Forest Products Journal

Vol. IX, No. 6 June, 1959

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ROTARY VENEER CUTTING

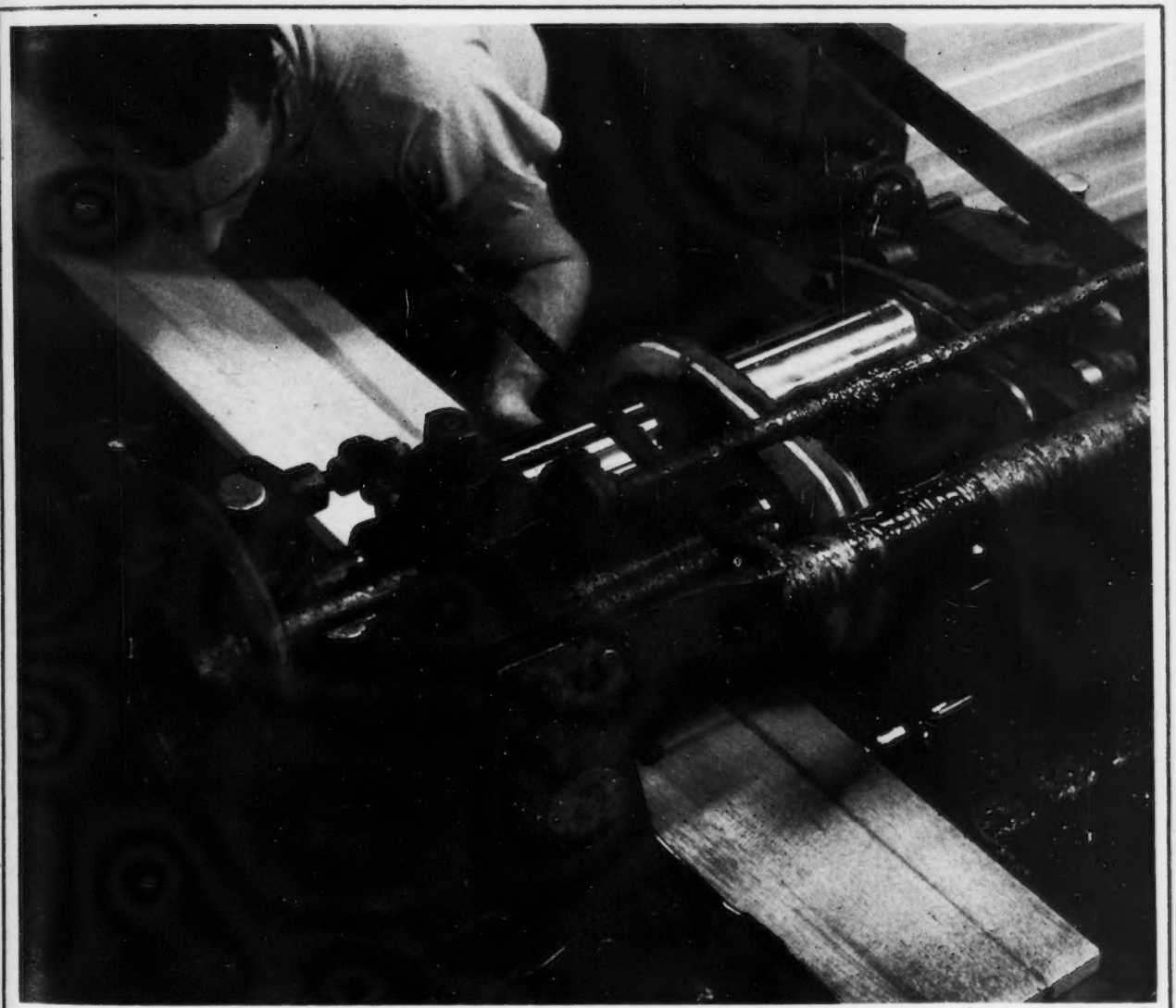

photo courtesy Koppers Co.

TROUBLE-SHOOTING GLUES AND GLUING

Symptoms to look for and corrective action to take, as discussed at the Wood Industries Conf. p. 11-A

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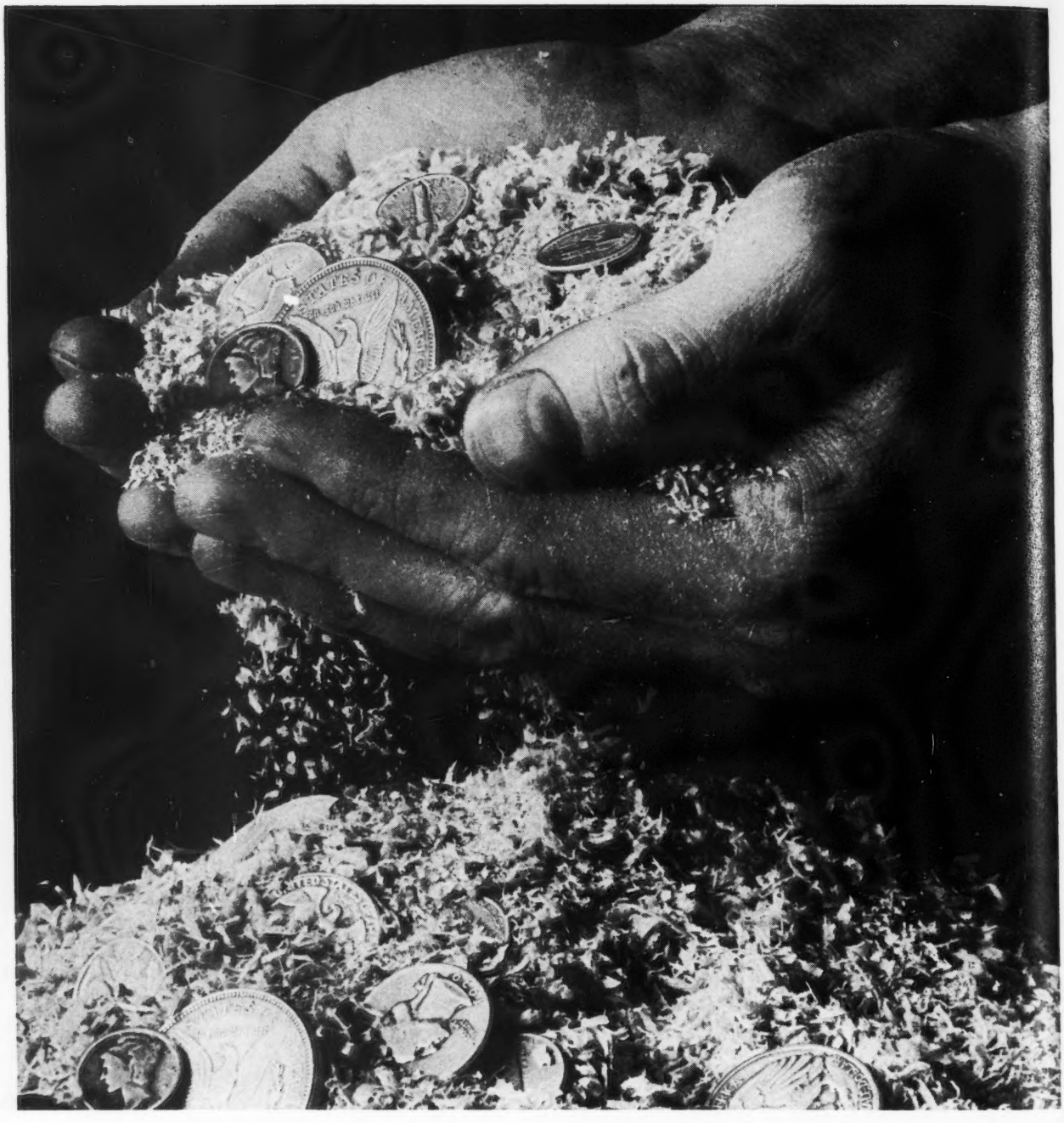

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FOREST PRODUCTS JOURNAL

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CAROLINA FOREST PRODUCTS reports on two-year performance of Washington flakeboard press

In the top photo is the Washington 8-opening hot press, elevator-type loader and injector, continuous recording device, pump unit and controls for automatic operation. In the smaller photo is the unloader and the ejector unit. On this equipment, flakeboard can be produced in thicknesses from 3/8" to 1¼" in 5' x 8' panels, with a range of densities from 32 lbs. to 48 lbs. per cubic foot.

• • •

Washington-built presses and accessory equipment units are in operation in, or have been ordered by, particle board, flakeboard and wet and dry process hardboard plants throughout the United States, in Cuba, Japan, Canada and Australia. Eight of these outstanding board producers, including Carolina Forest Products, Inc., are featured with photographs and data in a new 16-page brochure "Washington presses and accessory equipment." Your copy is available **FREE** by writing to Washington Iron Works.

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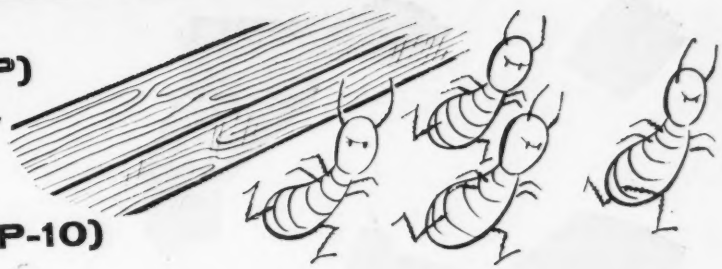

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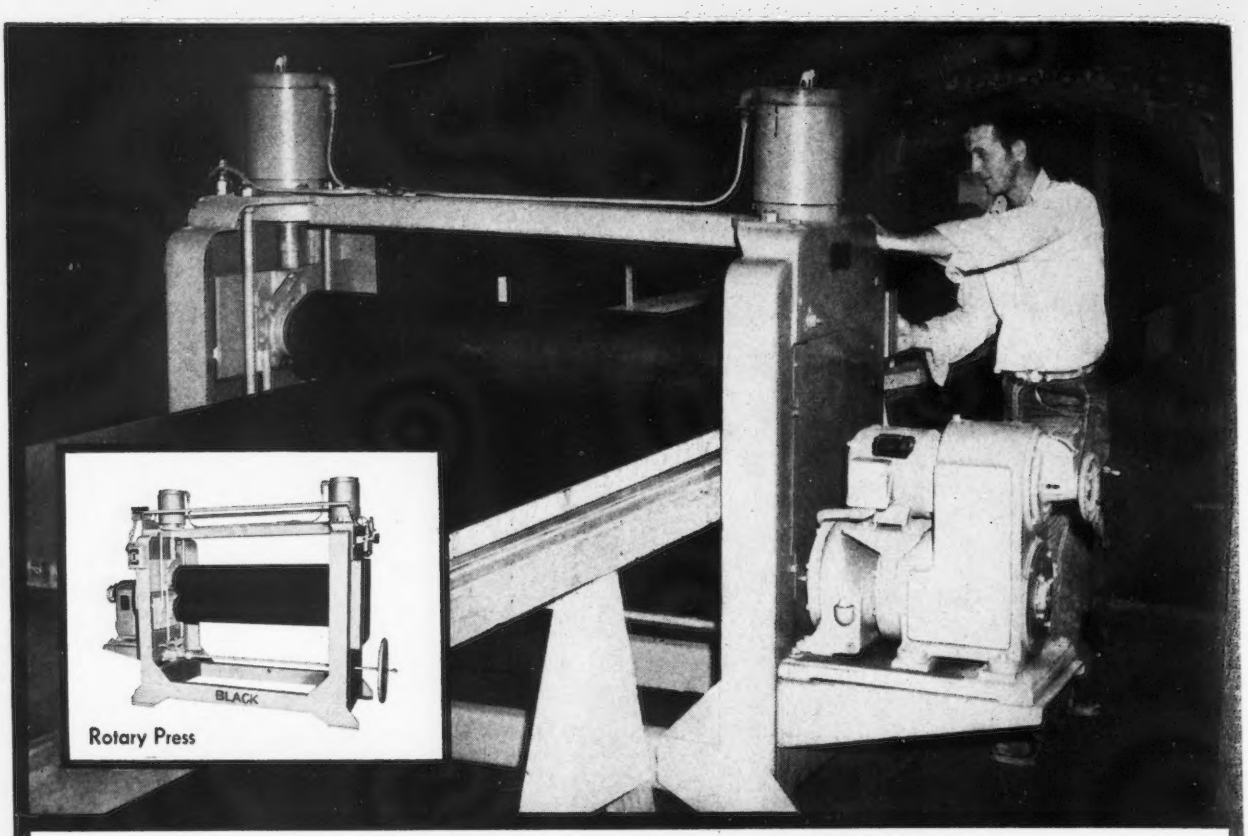

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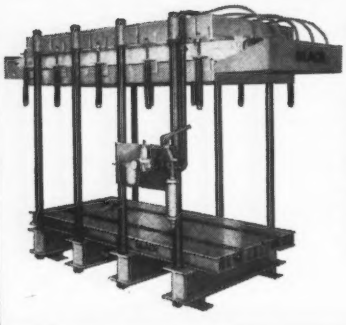

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Bulletin 11-D

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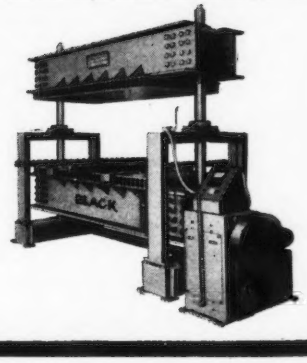

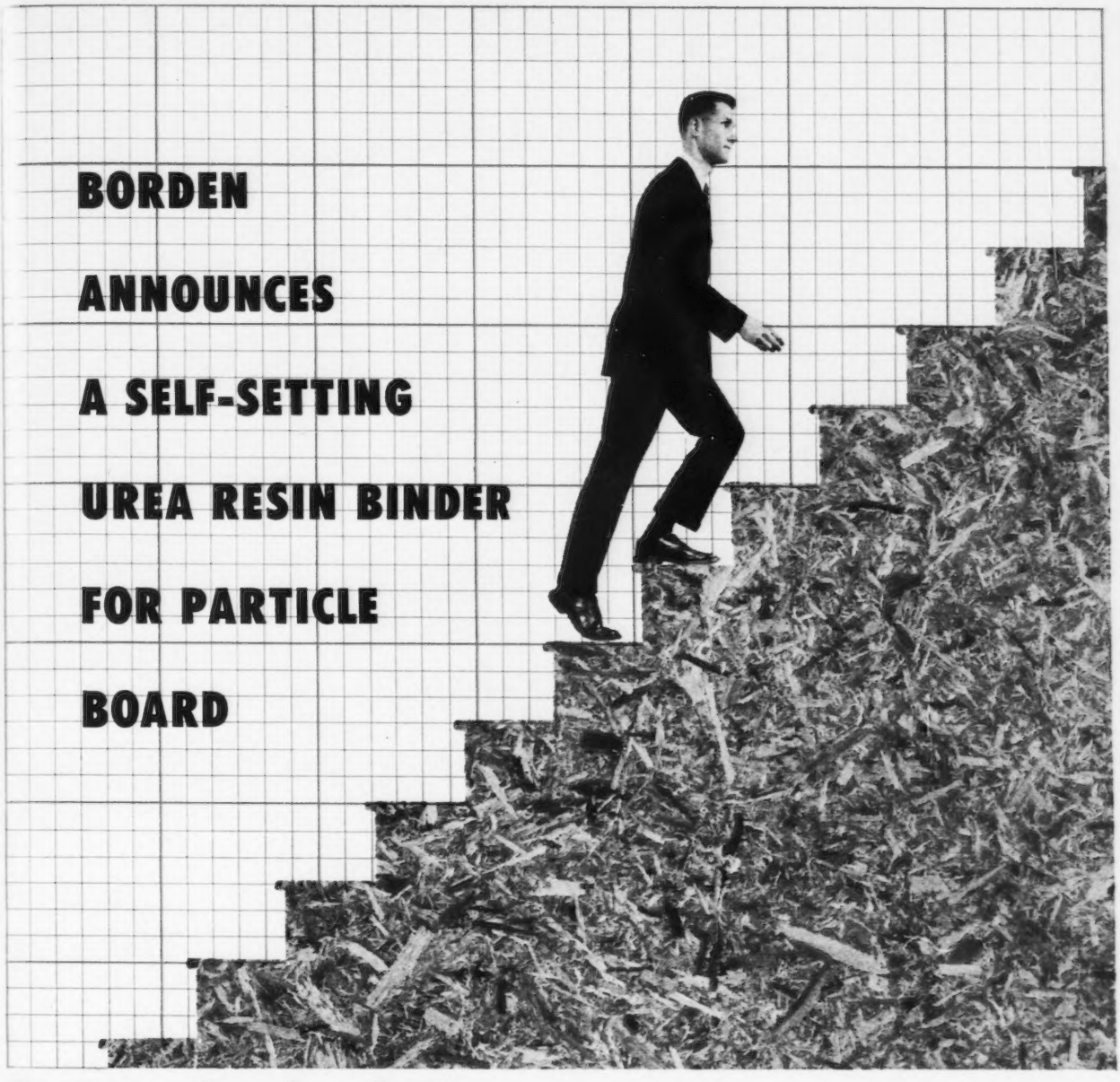

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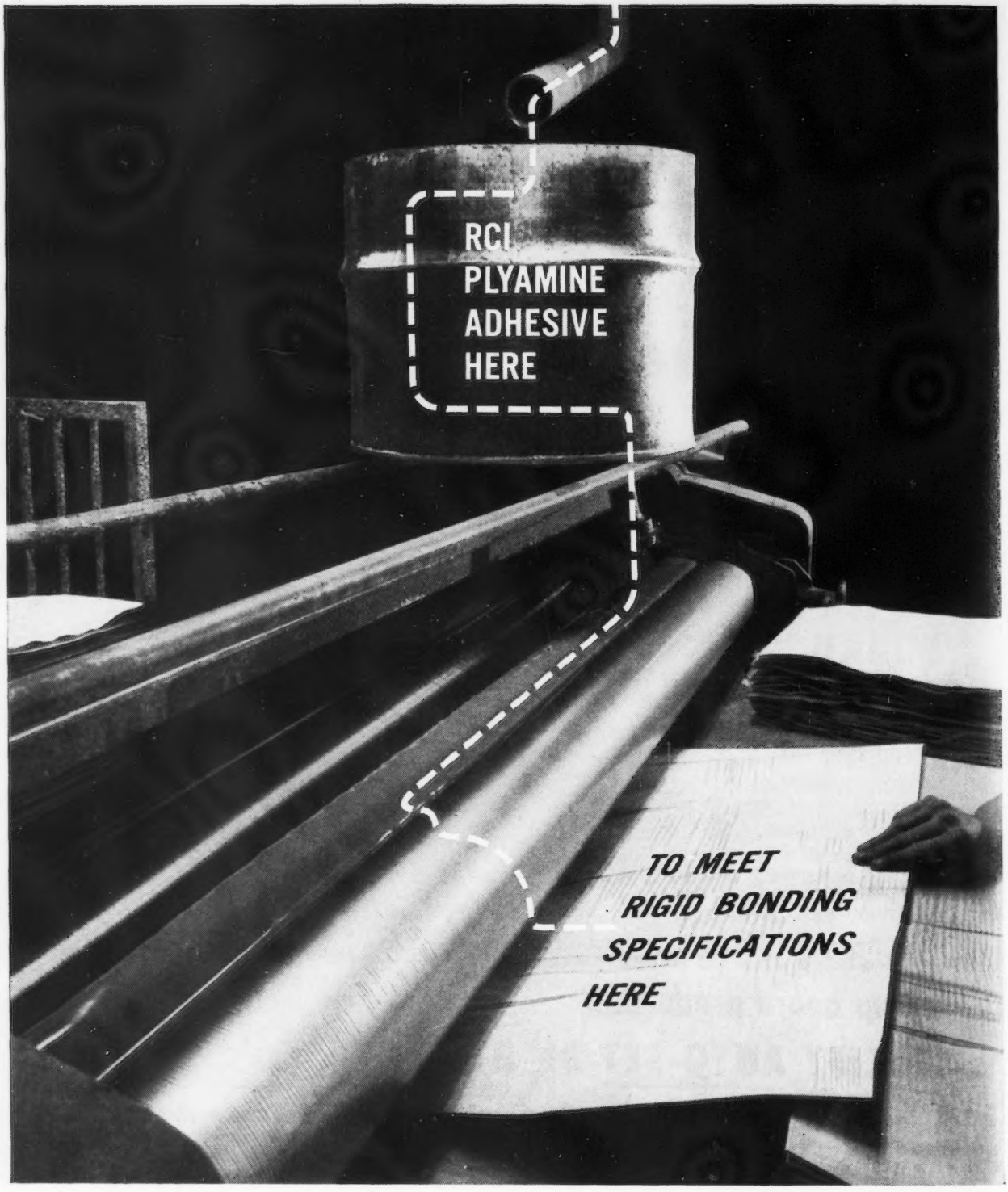

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CREATIVE CHEMISTRY...YOUR PARTNER IN PROGRESS

FPRS News-Digest

President's Column

In my final communication as president to the membership of the Society, I want to discuss several subjects that have been points of discussion during the past year, and indicate the progress that has been.

The first subject is the status of the Divisions within the framework of the Society. In this regard, Ray Berry has done a great deal of work and has formulated a program for giving status and dignity to the Divisions. His program is very complete, and I shall not attempt to outline it in this note, except to say that his ideas have been passed on to the members of the National Board Committee appointed for the framing of additions to the by-laws to implement a program for creating an actual status of Divisions and clarifying their position. This committee is to report at the San Francisco Board Meeting. Any suggestions brought before this Board, or brought up as a result of the Board Meeting, will be welcomed by your Executive Board.

A corollary subject is the objectives of the Division program. There have been times when certain Divisions have been unable to fill their programs with high-quality papers, and a few papers have been given that were not of the quality that we would like to have. The Executive Board is certainly cognizant of that fact, and it is one of the reasons that we are putting so much effort at this time on a better understanding of the importance of Divisions and the clarification of their status.

Certainly, programs and interesting papers are the main reason for the existence of the Society. There is one factor, however, that will always be a very delicate one as regards the membership. Our membership consists of scientists, teachers, and practical operating men. We cannot do research without scientists, and we cannot put research into use without production men. There will always be, I think, a delicate balance between how much scientific and how much practical material should be presented.

The trade journals think, and let it be known strongly, that practical papers should be for them, and that we are infringing their area when we publish practical papers in the Journal. However, a large segment of our membership likes practical papers. The scientists, on the other hand, may feel that only technical and highly scientific papers should be presented and published. Those of us who must manufacture products for a profit realize that both are necessary, and it is our aim to keep our meetings and our JOURNAL fairly balanced with the two types of subject matter.

A third point is membership of the Society. We did achieve a normal growth in the past, but membership has been dragging. We remained static for about a year during and for a few months after the recession that the wood industry felt in the recent past. This retarded growth has now, we think, been overcome, and the membership is again on the increase. In the Mid-South Section, of which I am a member, we have gained 42 new members in the past year—more than any other Section in the U. S., incidentally—and about 8 or 10 more men will be coming in in a very short time.

The fourth, and final, major point concerns the services the Society provides its members. There are some people who do not feel that the Society is providing proper service to its members. The reason, to my way of thinking, is very likely because we have not done as much salesmanship in our Society as we should have. We cannot expect every paper, every JOURNAL, or even more than a very low percentage ofeither of these, to be of value to any particular person. But if the members read the JOURNAL and attend the meetings, and if they show the proper alertness in either case, they can and will get a great deal out of both. And if they only get one or two ideas every two years, it will pay them to be members in our Society.

I was at one Section meeting where two of the papers were very bad—strictly advertising. On the other hand, some of them were good, and the very good turnout at this Section meeting resulted, to my knowledge in a great deal of interchange of thought that certainly was beneficial to a number of people, and one or two instances, it was certainly beneficial to me. I think

A meeting of the newly named "FPLC Committee on the Utilization of Wood Residues", under the chairmanship of Col. J. H. Jenkins, was held on May 28, 1959, at the Ottawa Laboratory of the Forest Products Laboratories of Canada. The change in name from "Research Co-ordinating Committee on the Utilization of Sawmill Residue for Pulp" was decided to cover expanded activities. Above, the Committee is in a lively panel discussion on problems encountered in the use of sawmill residue for pulp.

IMPORTANT FPRS DATES

Sept. 10–12, 1959: Joint A.S.M.E., A.I.Ch.E., Pacific Northwest—Inland Empire Section Meeting, Portland, Ore.

Oct. 6–7, 1959: Great Lakes Section Meeting, Detroit, Mich.

Oct. 11–12, 1959: Mid-South Section Meeting, Beaumont, Texas.

Oct. 29–30, 1959: Northeast Section Meeting, Worcester, Mass.

June 5–9, 1960: Fourteenth National Meeting, Montreal, Quebec.

we need to do a little more selling of our services, in addition to the ever-conscious need for improvement in quality.

I am looking forward to seeing as many of us as possible in San Francisco and at future meetings of the Society, and hope you will get in touch with your executive officers on the subjects in which you are sincerely interested. It has been a distinct pleasure and an honor to serve as president of the Forest Products Research Society and as a member of your Executive Board over the past six years.

W. Jeter Eason

Twenty-eight persons attended the Midwest get-acquainted meeting in Madison.

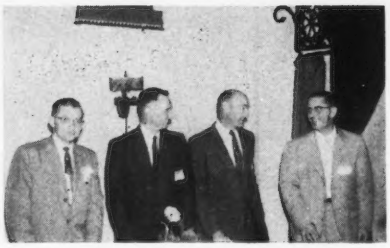
Natural Durability vs. Preservatives

In the May, 1959 issue of the FOREST PRODUCTS JOURNAL there appeared, on page 29-A, the following statement: "Today's properly preserved Douglas-fir, gum, oak, southern pine, and other commercial species will long outlast Nature's so-called durable woods with their limited resistance to decay and attacks by termites and other insects."

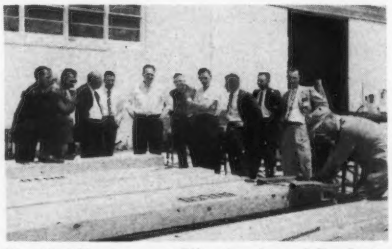
This misleading statement has brought protests from some segments of the forest products industry, and in support of their protest, we quote the following passage from the WOOD HANDBOOK, Handbook No. 72, U. S. Department of Agriculture, page 45: ". . . broad groupings of many of the native species, based on service records, laboratory tests, and general experience, are helpful in choosing woods for use under conditions favorable to decay. The following list shows (1) species with heartwood that is high in decay resistance, giving generally satisfactory service where decay hazards exist; and (2) species with heartwood that is moderate to low in decay resistance, usually requiring some form of preservative treatment to give satisfactory service under conditions that favor decay." Group 2 will not be presented here. Group 1.—Species with heartwood of high resistance to decay.

Softwoods	Hardwoods
Baldcypress	Catalpa
Cedars	Chestnut
Junipers	Locust, black
Redwood	Mesquite
Yew, Pacific	Mulberry, red
	Osage-orange
	Walnut, black

Editor



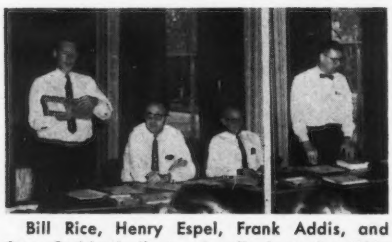
At the Upper Mississippi Valley meeting, Albert Lea, Minn. (l. to r.): Steve Wise, Wayne Meek, Paul Lane, Walter Wallin.



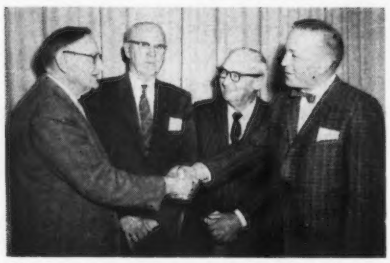
The U.M.V. group at Rilco Laminated Products.

Messrs. Williams, Ramos, Rowe, Boller, and Mabesa at the Midwest social meeting at Madison.

Ed Locke, John Rowe, and Frank Rovsek discuss membership at the Madison meeting.



Bill Rice, Henry Espel, Frank Addis, and Stan Suddarth (l. to r.) talked at the Ohio Valley Section meeting in New Albany, Ind.



Old-Timers were honored at the Inland Empire Section meeting, Spokane, Wash.

The evening panel at Albert Lea included Bob Thompson, moderator, and Bill Lewis, Charles Gray, Jack Forciea, Bill Coffman.

Representatives from 3M at Albert Lea.

Research associates at the FPL from Pakistan and the Philippines meet the manager of Page and Hill Homes at Albert Lea.

Primarily millwork people turned out for the Midwest get-together at Clinton, Iowa.

FPRS membership meeting at the Southern Pine Machinery Exposition, New Orleans. Top (l. to r.): Bill Hopkins, Jerry Saeman, Jim Byrne; bottom (l. to r.): Mark Lehrbas, Dick Warner, Tony Veasey.

10th Wood Award Winners Announced

The first-place winner in this year's "Wood Award" competition, sponsored by WOOD AND WOOD PRODUCTS magazine, is Arno P. Schniewind, who submitted his entry through the University of Michigan. The title of the winning paper is "The Transverse Anisotropy of Wood as a Function of Gross Anatomic Structure". The second-place winner was Harlan Freeman, of Yale University School of Forestry.

Dr. S. B. Preston, chairman of the judges for the competition, and Dr. James S. Bethel, chairman of the FPRS Industry–Education Division, made the announcement of the winners. J. F. Koellisch, editor of WOOD AND WOOD PRODUCTS, is to present the certificate and $350 cash award to Mr. Schniewind at the Official Luncheon of the National Meeting in San Francisco, Tuesday, June 30. The other two judges of the competition were Dr. Fred Brown, Dow Chemical Co., Midland, Mich., and Dr. R. L. Youngs, U. S. Forest Products Lab., Madison, Wis.

Schniewind holds BS and MS degrees in wood technology from the University of Michigan, and for the last three years has been doing research in absentia for his PhD from Michigan while on the staff of the Timber Mechanics Section of the University of California Forest Products Laboratory, Richmond. His paper is scheduled for presentation at Session VIII, Wood Drying (A) at the National Meeting.

Yale Entry Places Second

"An Analysis of Some Physical and Chemical Properties of Wood Related to Adhesion" is the title of the second-place winner, submitted by Harlan Freeman, of Yale. Freeman holds a BS in wood technology from the University of Minnesota, and is currently working for his MF at Yale. He will receive a certificate and a $150 cash award.

Nine Schools Represented

Ten entries from nine colleges and universities made up this year's competition. Although there were more entries last year, the number of schools represented was greater this year. The remaining eight entries were: "Wet Strength of Polyethyleneimine-Treated Paper", Cyril Geacintov, New York State University College of Forestry, Syracuse; "Grading Southwestern Ponderosa Pine Lumber Logs", John Henley, Colorado State College, Fort Collins; "Collapse and Its Removal in Pacific Madrone", Eugene Bryan, University of California, Richmond; "Effect of Certain Variables on the Strength of Glued End Joints", Kendall Bassett, Pennsylvania State University, University Park; "Relationship of Flake Size and Resin Content to Mechanical and Dimensional Properties of Flake Board", Paul W. Post, Pennsylvania State University; "The Specific Gravity of Red Pine as Related to Stem- and Crown-Formed Wood", Glenn A. Cooper, Iowa State College, Ames; "The Effects of Variations in Moisture Content and Percentage of Summerwood on the Preservative Treatment of Southern Pine and Douglas-Fir by the Cold-Soaking Process", James H. Zeagler, Louisiana State University, Baton Rouge; and "Some Aspects of the Behavior in Flexure of Creosoted Glued Laminated Douglas-Fir Beams Containing End Joints", Karl G. Tamberg, University of Toronto, Toronto, Canada.

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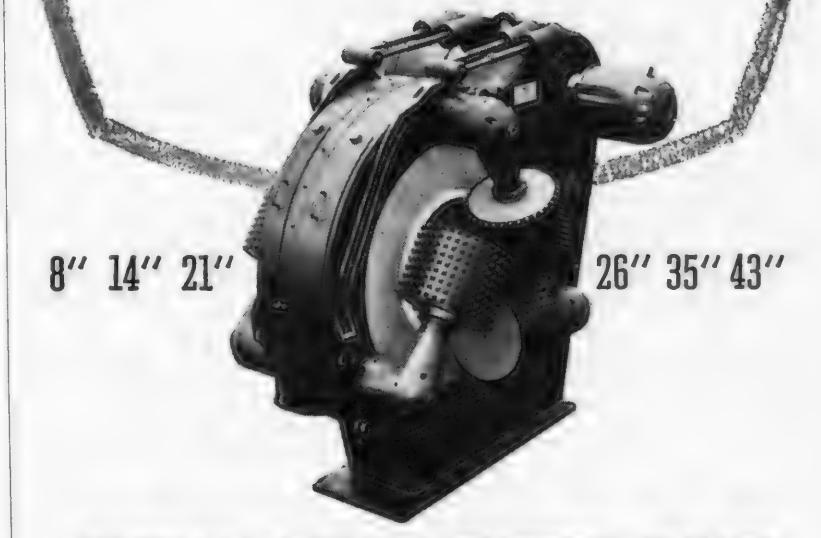

8" 14" 21" 26" 35" 43"

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485—U. Minn. grad, BS in wood tech. 7 years experience in gluing and laminating production and QC. Desires QC or development position in end and edge gluing. (June)

550—Industrial forester, utilization major, wants change with advancement possibilities. Exp. includes sales, administration, scaling, grading, tallying, etc. (June)

551—Iowa State grad, BS in wood tech, desires position in production, sales, or research. (June)

552—Wood tech MS desires research or production engineering. Background includes math, physics, statistics. (June)

554—Young exec. desires sales or production position, prefers Mid-Atlantic states. Exp. in wood parts includes research, product development, manufacturing, sales, administration. (June)

556—BS grad. in wood utilization from Penn. State U., interested in furniture production, finishing, seasoning, and packaging, possibly selling.

557—Wood products engineer, BS and MS from State U. of N. Y., Syracuse, desires position in management, product development, or technical service. Presently on staff of university, avail. Oct.–Nov.

558—LSU grad. with BS in forestry, utilization option, desires work in production or preservation.

559—Jr. economic analyst seeking opportunity with integrated products firm that potentially will lead to position as forest economist and/or operations and planning analyst. Will relocate anywhere. Has unique combination of both experience and education in economics, forestry, and engineering.

560—BS grad. in wood utilization desires position in research, development, or production.

Positions Offered

E-353—Position available for outstanding man who has ability to advance. Large, integrated progressive store-fixture plant. Midwest location. Send resume.

WANTED

Wood technologist, chemical engineer, or chemist, preferably with some experience in paper or plastics manufacture, to take charge of production processes, development and laboratory work, reporting to technical director of growing Mid-West plastics laminating firm. Excellent opportunity to associate with a growing industry in the research field.

Send replies to:

E-354, Employment Service
FOREST PRODUCTS RESEARCH SOCIETY
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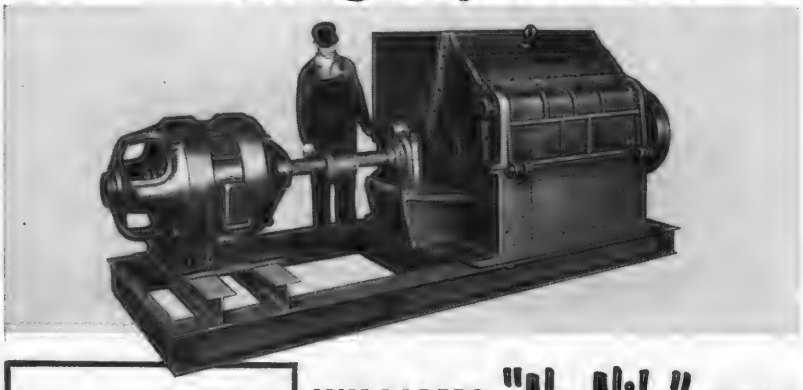

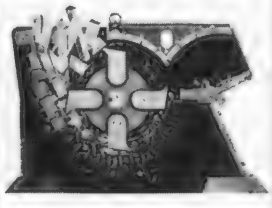

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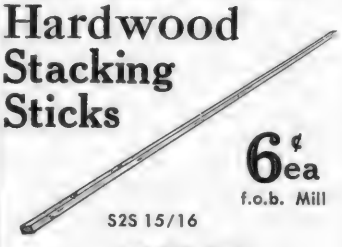

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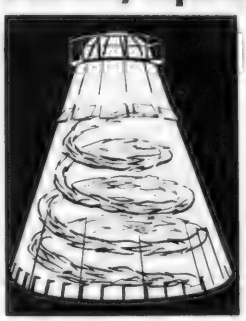

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FPRS FOREST PRODUCTS JOURNAL VOL. IX, NO. 6 JUNE, 1959

FOUR EXPERTS DISCUSS

Trouble Shooting Glue Problems[1]

Animal Glues for Assembly and Edge Gluing

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WHILE ANIMAL GLUES ARE among the most trouble-free wood adhesives in use, it must be assumed that even in the best-run woodworking plants, gluing defects occasionally occur. Good management with an adequate quality-control program will recognize these defects almost as soon as they occur, and take immediate steps for their correction. In this way, any loss in either materials or labor will be minimized. It is beyond the scope of this paper to discuss in detail gluing quality-control programs, although their importance cannot be overemphasized.

The first step in trouble shooting any bonding difficulty is to become familiar with the appearance of the various types of defects encountered. After the poor bond is classified by its appearance, the cause or causes of the defect can be readily determined. While sometimes the exact cause of a poor bond can be determined by examination of the defective part alone, it is generally necessary and always wise to review the entire gluing process. This survey would include all factors involving wood and glue preparation as well as actual gluing technique. Variations from recommended practice correlated with the type of defect found will locate with great certainty the cause or causes of the unsatisfactory glue lines.

Once these causes are located, the steps for their correction will be self-evident.

The trouble shooting of animal glues in wood gluing operations will be presented in four parts as follows:

1. The trouble shooting of hot animal glues in edge gluing.
2. The trouble shooting of hot animal glues in assembly gluing.
3. The trouble shooting of liquid animal glues in edge gluing.
4. The trouble shooting of liquid animal glues in assembly gluing.

Trouble Shooting Hot Animal Glues in Edge Gluing

Description of Defects: Many edge-gluing defects are invisible until discovered through either accidental or intentional breakage of the panel. However, these defects may also show up as open glue lines sometime after gluing. This may happen at any time when stresses from ordinary variations in humidity finally overcome the strength of the weak bonds.

The most common readily visible defect in edge-glued panels is end checking. This defect occurs almost entirely during the winter heating season, and then usually only in unhumidified plants. It is not unusual to find the equilibrium moisture content in heated, unhumidified plants in the range of 2 to 3 percent. The result is that very rapid drying accompanied by shrinkage takes place at the exposed ends of panels and other stock. The end checking brought about by this low plant humidity may or may not be indicative of a true gluing defect. If examination of the panels shows that checking has taken place as much in the wood as in the glue lines, then the gluing operation is probably satisfactory and the only solution is proper humidification.

If end checking has taken place only in the glue lines, then this is a sign that these bonds are weak. The cause of weakness can then be determined as with any other type of defective glue line by opening the joints, visually classifying the type of defect, and then determining its cause. The visual classification of poor glue bonds is the key to accurate determination of their causes, and the following describes how the various defects appear.

Starved joints: Starved joints are by far the most common defect found in edge-glued panels bonded with hot animal glue. Ironically, many starved joints are produced almost intentionally by the manufacturer as a result of leaning over backwards to avoid the opposite (chilled joints), which actually seldom occurs.

When a starved joint is examined, it is weak and shows little or no wood failure. Careful examination of the surfaces will show very little or no glue on the wood. Indeed, the wood will have the appearance of never having been spread, although actually a very heavy spread may have been used. If the glued surface is moistened it may or may not become tacky, but there definitely will not be a continuous film of glue present on the surface.

In concluding the description of starved joints, it should be reemphasized that this is the most common defect encountered and yet one of the most difficult to determine. It may be almost unequivocally stated, however, that if the bonds are weak, show little wood failure, and there is little or no evidence of a continuous glue film, such joints are starved.

Poor contact: The second most common gluing defect in edge-glued panels is poor contact. When the surfaces of such bonds are examined, heavy but irregularly spaced deposits of glue will be observed. These will often be in areas where the gluing surface is visibly very rough or for some reason distorted. If contact is very poor, these heavy glue deposits will have a distinctly shiny appearance, which will indicate that the spread surface made no contact whatsoever with the opposite bonding face. Poor contact may also often be recognized in unbroken panels by open glue lines occurring at random in various parts of the panel, or by the appearance of heavy glue lines of irregular width. Although the causes of poor contact are for the most part obvious, the detailed reasons for this type of failure will be discussed later.

Chilled joints: Chilled joints are among the least common of joint defects encountered. This was not

[1] Panel discussion held the Wood Industries Conference (joint meeting, FPRS Northeast and Eastern Canadian Sections, ASME Wood Industries Division), March 30–April 1, 1958, Syracuse, New York.

always true, but has come about since the majority of plants are now adequately heated and have sufficient room-temperature storage space for lumber.

This type of weak bond may be recognized in the glued panel by unusually wide, highly visible glue lines. When the panel is opened and examined, a very heavy glue film will be observed on all or most of the bonding surface. In the case of very well mated surfaces, contact may be almost complete along the joint area, or more likely it will be spotty. The heavy glue film will, ordinarily extend all along the bond, however.

Miscellaneous defects: Weak bonds may also result from burning or burnishing of the surface to be glued, or from foreign matter such as oils and waxes. The appearance and cause of such defects should become obvious upon examination.

Cause of Defects: With a clear visual picture of how the various types of defective glue lines appear, it is now fairly easy to locate their cause and then take necessary steps for their correction.

In the edge gluing of lumber on clamp carriers, two factors are usually considered fixed for any particular operation. These are the amount of pressure applied and the assembly time used. The operator usually applies as much pressure as he is able to maintain throughout the day, and in the interests of maximum production, assembly times must be kept to a minimum. In making strong wood to wood bonds with animal glues, the following rule is of the greatest importance: *gluing factors must be controlled to provide a thin but completely continuous glue film between the bonded surfaces.*

This means that pressure and glue consistency must be correlated at the moment pressure is applied to produce the thin but continuous film previously mentioned. Since pressure cannot be practically changed in a clamp carrier, glue consistency at the time of pressing is the key to good gluing. Conversely, the majority, although not all, poor bonds obtained by misuse of animal glues are due to the improper relationship of pressure and glue consistency.

Cause of starved joints: Starved joints are caused almost entirely by applying pressure to a glue film that for one reason or another has not reached a high enough viscosity. The result is that the thin glue penetrates excessively into the open wood cells and is also squeezed out. Such bonds will have the appearance previously described, and gluing process should be checked for the following possible causes. The indicated corrections can then be made.

1. Glue Mixed Too Thin. A glue mixed too thin, because manufacturers' recommendations were not followed or known for the particular operation, is the greatest cause of starved joints. Also, even though the correct proportions are known, careless weighing or other poor preparation procedures may cause variations in consistency.

2. Glue Too Hot. A glue that is too hot will not cool sufficiently to be of adequate consistency when pressure is applied. The recommended temperature is 140°F., although lower temperatures to 120°F. may also be used if correlated with the rest of the gluing process. Lack of accurate glue-spreader temperature control will produce glue of varying temperatures and therefore different consistencies.

3. Wood Heated. The heating of wood on steam tables or by other means raises its temperature so that applied glue cannot cool and thicken slightly before the assembly is clamped. It used to be necessary to heat stock where no provision was made for the wood to reach room temperature prior to gluing. Today, the practice of heating wood prior to gluing with animal glue is a common cause of starved joints and it should be discontinued.

4. Excessive Spread. Excessive spread in an otherwise well-balanced gluing operation can also be the cause of starved joints. Although this fact seems inconsistent, a large amount of glue cools more slowly in air and thus will not increase in viscosity so fast as a thinner spread. Unfortunately, the first thing often done to overcome starved joints is to increase the spread, since this type of defect would seem to indicate that an insufficient amount of glue has been applied to the surfaces to be bonded.

5. Low Wood Moisture Content. Although wood moisture content is not a factor that affects glue consistency, low moisture contents (below 5 per cent) may contribute to starved joints by absorbing excessive amounts of glue and leaving an inadequate amount on the surface to form the bond.

Cause of bonds showing poor contact: Glue bonds that show poor contact are the direct result of improper machining or stock preparation procedures. More specifically, the following are the causes of this type of poor joint.

1. Poorly Adjusted or Maintained Equipment. Straight-line rip saws and jointers need to be adjusted so that they produce straight, smooth surfaces that fit together closely along their entire length. There should not be any bow visible when pieces are placed together prior to being glued. Worn bearings, feed chains or other machine parts will not hold the close tolerances necessary to cut good glue joint surfaces, and they should be replaced. It is axiomatic that knives and saw blades should be sharp and properly fitted to give smooth cuts with no tooth marks or other irregularities.

2. Poorly Flattened Stock. Stock that has not been properly flattened prior to ripping will often produce glue joints that are not square. This leads to clamping difficulty, bowed panels, and also joints with poor contact on one side. An ordinary planer will not flatten stock properly, and a facer should be used for this work.

3. Too long An Interval Between Machining and Gluing. If stock is not glued very shortly after its preparation, moisture changes (either gain or loss) will distort it and make the surfaces unfit for gluing. Many of the best gluing operations glue directly from the jointer or rip saw, thus preventing any dimensional changes in the wood.

4. Poor Seasoning Procedures. Improperly dried lumber containing stresses will distort when ripped, and even though the rip saws may be perfectly adjusted, the joints obtained will be bowed or otherwise warped. Proper kiln drying practice will insure that this does not happen.

Cause of chilled joints: Chilled joints are the opposite of starved joints, and are due to pressure being applied to a glue film that has already reached a firm gel. In looking for the cause of chilled joints, many of the same factors as shown under starved joints should be investigated, but we would expect to find them of opposite magnitude as follows.

1. Glue Mix Too Heavy. Follow manufacturer's recommendations for the application.

2. Glue Too Cool. Glue temperature so low that the adhesive jells almost immediately after it is spread.

3. Wood Too Cold. As previously mentioned, heating the wood prior to gluing is not necessary. It should, however, be at room temperature (70–75° F. minimum).

4. Room Too Cold. Room temperature should ordinarily be a minimum of 75° F.

5. Excessively Long Assembly Time. Long assembly times used without compensation and adjustment of other factors such as mix, and so on.

Trouble Shooting Hot Animal Glues in Assembly Gluing

Description of Defects: Defective assembly joints cannot be classified in the same way as can edge-glued bonds because of their smaller areas and the similarity of appearance for a large number of causes. They can, however, be visually described as follows.

Little or no glue film apparent in the joint: When examined, a poor bond as described above will show little or no glue on the areas that were bonded. This does not necessarily mean that an inadequate amount of glue was applied, although this is one of the possible causes. This type of defect is most commonly found in dowel or chucked joints.

Excessive glue deposit in the joint: Joints that fit this description show very definite heavy glue deposits on one or both parts of the assembly. Shallow mortise and tenon joints may particularly show this type of defect.

Cause of Defective Assembly Joints:

Little or no glue film appearing in the joint:

1. Glue Too Thin or Too Hot. If the glue when applied is either too thin or too hot, it will be forced away from the mating surface when the two surfaces are joined. Manufacturer's recommendations should be followed for the glue mix, and glue temperature should ordinarily be 140° F.

2. Inadequate Joint Clearance. Where joints that have no tolerance at all are forced together, the glue is stripped from the mating surfaces. Such a bond will not retain an adequate glue film, and the result will be a weak assembly that will eventually come apart. Since assembly joints such as dowels must usually be self-clamping in the manufacturing process, a compromise must be reached between the ideal joint clearance (1/64–2/64 inch) and a fit where the assembly will hold together without clamping until set.

3. Insufficient Glue. In assembly gluing, it is not uncommon to find that an inadequate amount of glue has been applied. In these cases when the assembly is put together, the amount of glue is not sufficient to spread over the entire area of the joint and a weak bond results. Inadequate spreads are often used almost intentionally in an effort to avoid squeeze-out and thus the necessity for clean-up. It is, however, quite possible to apply adequate glue spread and yet still not so much that excessive squeeze-out results.

Excessively Heavy Glue Deposits: Defective assembly joints are seldom caused by use of a glue that is too high in consistency either by virtue of being mixed too heavy or used at too low a temperature, because such glues are not readily hand spreadable and a correction in consistency must be made before the glue can be easily applied. The occasional exception to this is the infrequent incident of chilled joints where assembly times are exceptionally long. Glue joints that are weak and show heavy deposits of glue are usually caused by poor machining of the components. This type of defect is fairly often encountered in shallow mortise and tenon joints.

Other causes of defective assembly joints: Weak assembly bonds are also caused by dull boring or mortising tools. If the joints are burned or burnished, satisfactory adhesion cannot take place even though the fit of the joint may be very satisfactory.

Trouble Shooting Liquid Animal Glues in Edge Gluing

Description of Defects: Starved joints, poor joints resulting from incomplete contact, and weak joints resulting from excessively heavy glue lines (appearance similar to chilled joints) can result from improper use of liquid animal glues. The appearance of these defects, when the bonded surfaces are examined, will be similar to the description of defective joints obtained when hot glues are used improperly in edge gluing.

Cause of Defective Joints: While there are less variables involved in locating the causes of defective joints made with liquid animal glues, a similar principle applies. That is, it is important for best results that consistency at the time of clamping be related to a given pressure and assembly time. Failure to consider this principle can result in defects caused as follows.

Starved joints:

1. Wood or Glue Heated. Since liquid glues are intended to be used at room temperature, an increase in wood or glue temperature will lower the viscosity of the applied glue at the moment of pressing. Starved joints will then be the result.

2. Excessive Spread. In critical gluing operations where high strength is required, a heavy spread will not dry and thicken enough with short assembly times to provide the best consistency at the time of pressing. Thin spreads, since they will dry and thicken slightly faster, result in a much more satisfactory glue consistency at the time of pressing. This is especially true where high pressures are used.

Incomplete contact: The causes of bonds showing poor contact are, of course, the same for all adhesives and are as previously outlined.

Excessively heavy glue lines: While excessively heavy weak glue lines are uncommon with liquid animal glues, such a condition may occur where wood and glue temperatures are well below normal and clamp pressures are low.

Trouble Shooting Liquid Animal Glues in Assembly Gluing

Description and Cause of Defective Assembly Joints: Poor assembly joints made with liquid animal glues have the same appearance as those made with most other glues. On examining the majority of defective bonds, there will be either an almost complete absence of glue or a very heavy deposit. Where there is little or no glue visible in the weak joint, the probable cause will be one of the following: insufficient tolerance in the joint, liquid animal glue inadvertently heated, or insufficient glue applied.

Where assembly joints are weak and show heavy deposits of glue, the cause will be excessive clearances and poor machining of the assembly.

Urea Resins for Hot- and Cold-Press Hardwood Plywood

C. C. Booth
The Borden Chemical Co., Bainbridge, New York

THE TECHNIQUE OF MAKING hardwood plywood is an interesting and fascinating art in which good equipment, trained personnel, and skilled supervision must be combined. Bonding conditions must be closely controlled to produce quality plywood in today's competitive market.

While it is natural enough to blame the glue for faults not easily traceable to equipment, supervisors and operators skilled in "trouble-shooting" are in the majority of cases able to determine the nature of the problem, then locate and correct difficulties.

The object of this paper is to describe typical gluing faults that might be encountered, point out their causes, and recommend steps for overcoming or eliminating them.

Gluing Defects

Although certain problems are directly related to the method of pressing plywood, that is, hot press or cold press, many occur in either procedure because of other conditions. A few of the outstanding gluing defects found in hardwood plywood with a short description of each are as follows:

Bleed-through: The glue mix penetrates to faces of panels. These areas are difficult to stain and finish despite sanding, which removes excess glue from the surface. It is more prevalent in hot pressing because of the greater flow of resin under heat.

Blows or blisters: This condition is identified by raised or ruptured areas on the face of panels, and usually occur in all-veneer constructions between core and crossbands. It is restricted almost entirely to hot-pressed panels.

Dimpling: Panel surface has wavy-like appearance. This defect becomes quite pronounced when the assembly is finished.

Face-checking: Identified by cracks or checks on faces of assemblies and occurs in both hot and cold pressing.

Indentations: Depressions found on faces of panels that are difficult or even impossible to conceal by finishing. Press conditions do not contribute to this problem.

Low water-resistance (but good dry strength): Construction fails to withstand usual tests for water resistance without showing signs of delamination. Occurs with either hot-or cold-pressed assemblies.

Pre-cure: This defect is found in both hot- and cold-press panels, although hot pressing is probably the more critical operation. It is easily identified in poorly bonded construction either by spotty transfer or no transfer of adhesive from crossband to faces or cores. Spreader marks are easily visible on crossbands.

Spotty bond or adhesion: Adhesion within panel is erratic, being good in some areas while very poor in other parts of a panel.

Starved joints: Characterized by very weak bond. Glue transfers from one surface to the other, but very little evidence of adhesive mix within the joint.

Warpage: Recognized by any variation from flat, true panel. Occurs in both cold and hot pressing, although more prevalent in the former application.

Weak bond: Construction exhibits very poor adhesion. Good transfer but glue line is powdery.

Probable Causes of Gluing Deffects and Suggested Methods for Correction

Recognizing a gluing fault in hardwood plywood production is only part of the "trouble-shooting".

It is equally important to determine how the incident occurred, and initiate steps to eliminate the possibility of future recurrences.

Some of the more common causes found in hot- and cold-press operations are summarized for simplicity in outline form with a short description of recommended measures for overcoming the difficulty.

Bleed-through: Adhesive mix too thin in consistency or viscosity: Reduce amount of water to provide a good spread. Assembly period too short: Permit longer time between spreading and pressing construction. Adhesive spread too heavy: Apply a lower spread. If the heavy spread is a result of rough, loose-cut, or porous stock, suggest improving veneer quality to reduce glue spread. Face veneers too high in moisture content: Use material with proper amount. It may be necessary to install dehumidifying equipment to accomplish this. Faulty type of extension: It is desirable to incorporate an inert filler such as nut shell flour into the mix as 10 to 25 percent of total extender.

Blows or blisters: Assembly time too short: A longer period is required. Adhesive mix is too thin: Body-up the formulation by reducing amount of water or increasing filler or extender ratio. Material to be bonded is too high in moisture content: Use stock at correct moisture, usually 5 to 10 percent. Moisture content of stock non-uniform: Wet spots are present. Avoid the use of materials with defects such as worm holes, knots, or dents. Do not use fillers that absorb and hold excessive amounts of water. Check panel lay-up to insure proper alinement of crossbands and core.

Press temperature too high: Recommend reducing platen temperature and using longer press time if necessary. Press time too short: Use a longer curing cycle. To accomplish this, it may be necessary to select a different catalyst, resin, or both. Presence of defects in stock: Improve the quality of material, avoid knots, worm holes and checks. The condition of the planer and veneer lathe should be checked to insure satisfactory operation. Spread of adhesive too heavy: Make certain that spreader is functioning properly. Rolls should be alined with each other and with doctor rolls. Regroove or replace worn rolls. Wash the machine frequently enough to keep clean.

Dimpling: Crossbands too thin or contain defects: Use thicker veneers to avoid "telegraphing" and improve quality to avoid knots and checks. Lumber core has defects: Utilize better stock to eliminate potential hazards. Non-uniform moisture content in particle board cores: It may be necessary to further condition the board to achieve uniformity. Also, it is suggested that material with reasonably uniform chip size be employed. Particle board has variable thickness: Board should be planed and conditioned before it is glued. Surface should be reasonably smooth and not pitted or full of voids.

Face-checking: Assembly improperly conditioned. Hot-press panels should be dead stacked and weighted for several hours to permit gradual cooling, or stickered to achieve rapid cooling. Cold-press constructions should be stickered for at least 48 hours to allow for moisture redistribution. Moisture content of stock too high: Use components at proper moisture content. Press period too long: Remove panels from press upon completion of curing cycle to prevent drying out. Do not leave assemblies on hot platens during break or lunch periods. Press temperature too high: Reduce platen temperature somewhat. Avoid excessive heat unless moisture content of stock is carefully controlled.

Indentations: Cauls or platens pitted or otherwise damaged. Keep surfaces clean, smooth, and coated with release agent.

Low water Resistance: Constructions tested too soon after bonding: Allow several days for maturing so that the glue joint can attain complete cure, particularly with cold-press panels. Mix extension too high or faulty: It is recommended that fresh, white wheat flour with low ash content and low water-taking capacity be employed. The amount of extension possible depends upon the degree of water resistance desired.

Pre-cure: Assembly time too long: A shorter period between spreading and pressing is necessary. A less reactive catalyst will also help. In hot pressing, use an automatic loader and rapid press closing time, if possible. Adhesive mix too reactive: A more retarded formulation is required. Determine mixing proportions, particularly powders, by weight and not by volume. Hot cauls employed: Cool boards by fans or other means. Hot veneers or cores: Make certain that materials are cooled before they are glued. Do not use stock directly out of kiln or dryer. Press temperature too high: Lower platen temperature, especially if moisture content of assemblies is high. Porous veneers: Use proper spread. In general, porous, rough, or loose-cut veneers require a heavier spread than dense material. Spread too light or non-uniform: Make certain that condition of spreader is satisfactory. Be careful not to wipe glue off crossband by sliding lumber core on spread veneer. Do not use gloves to smear glue around on surface of crossband or core. Stock has variable thickness: Be sure that all panels in one press opening are the same thickness. Avoid using veneers of unequal thickness in the same crossband or core. Lumber cores should not be planed to final thickness until a day or two before they are glued.

Spotty Bond or Adhesion: Assembly time is too long for certain areas: Warped or loosely piled veneers expose part of glue line (open assembly), which results in more rapid drying out. Use either a shorter assembly period or reformulate mixture to incorporate retarded catalyst system. Spreader rolls may be worn or damaged and need replacing. Careless veneer handling: More care should be taken in laying-up assembly. Do not smear glue with gloves or slide lumber cores on spread crossbands. Face veneers sized, burnished, or glazed: Watch the excessive use of adhesive in splicing so that squeeze-out along joint is minimized. Avoid coating cauls or platens with too much release compound. Do not use stock burnished in planing or veneer-drying operations. When sizing fancy face veneers, use minimum amount of mixture to accomplish objective. Insufficient or non-uniform pressure. Spliced veneers within a crossband should be of equal thickness. Make certain that all panels in one press opening are the same thickness. Check press occasionally to make sure it is not out of line and is delivering proper pressure. Improper mixing: Follow instructions of the adhesive manufacturer for order of addition of ingredients. Mixer should be clean and operate at speed of 50 to 60 rpm. It should not be filled more than 2 inches above top blade. Water temperature should be 60 to 70°F. Adhesive mix should not be agitated indefinitely. Likewise, the formulation should not stand for long periods before use; it is better to make more frequent, smaller mixes. Non-uniform adhesive spread: Spreader should be checked to insure proper operation. Rolls should have adequate grooving and be in alinement with each other and with doctor rolls. Avoid using stock that is rough, defective, or uneven in thickness. Non-uniform press temperature: Make certain steam traps are in operating order. Clean out channels in the platens if they appear to be water logged.

Starved Joints: Assembly period too short: Employ a longer time between spreading and pressing, especially with dense species. It may be necessary to incorporate a slower catalyst into the adhesive mix. Adhesive mix too thin: Reduce water ratio to give more suitable consistency. Excessive pressure: Reduce pressure somewhat. Some delayed assembly time may also be required. Faulty extension: Fresh, white wheat flour with low ash content and suitable water-taking capacity should be employed. It may also be desirable to use nut-shell flour up to 10 to 15 percent of total extender. Foamy mix: Make certain that mixer speed is 50 to 60 rpm. Water ratio should be just enough to provide proper spreading consistency. Spread too light: Increase amount of adhesive by spreader adjustment. It may be necessary to reduce water in the mix to obtain suitable mix consistency.

Warpage: Faulty-core stock: Improve quality by avoiding material with worm holes, dents, knots and burnishes. Do not employ different density woods in same core. Confine the width of core strips to 4 inches or less. After stock has been edge glued, allow to condition for a period of time before planing to preclude possibility of sunken joints. Improper conditioning of panel: Hot-press constructions should be allowed to cool gradually by means of dead stacking. Do not machine cold-press assemblies until they have matured several days. Non-uniform spread: Veneers and cores must have uniform thickness and be free of defects. Make certain that the spreader is in good condition: Over-curing in hot press: Remove panels from press upon completion of press cycle. Assemblies should not remain in press during breaks or lunch period. Press temperatures too high: Reduce platen temperature and lengthen cure cycle, if necessary. Unbalanced construction: The same species and thickness of veneers should be employed. Diagonal grain material is not desirable.

Weak bond: Adhesive mix not reactive enough: Select the correct resin-catalyst combination for the plant conditions. Adhesive representatives will be glad to assist on this problem. Follow the manufacturer's directions for mixing. Adhesive spread too heavy: Use proper spread for the formulation employed. Rough, loose-cut, and generally poor stock requires a heavier spread than smooth, dense species. Moisture content of stock too low: Be sure that the material is within the recommended moisture content range for the adhesive employed. In the case of lumber cores, do not surface too far in advance of gluing operation. Press cycle too short: When assemblies are cold pressed, make certain temperature is at least 70°F. The use of a "hot room" at a temperature above 100° will aid cure. For hot-press construction a little longer cure time will prove beneficial. Press temperature too low: Raise platen temperature or lengthen cure time for hot-press panels. Temperature should be at least 70°F. for cold-press constructions. Stock, particularly cores, too dry: Condition material to 5 to 10 percent moisture content. Humidifying unit may be necessary to insure suitable results.

Urea Resins for RF and Heated-Platen Edge Gluing

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To understand the problems of the radio-frequency and steam-heated-platen systems, it might be wise to discuss briefly the mechanical and chemical operations involved. The least complicated system is the steam-platen type, so it will be discussed first.

The glue is applied to the edges of the lumber, which is fed into a mechanism that pushes the stock between two heated plates, in the case of a continuous gluer, or the stock is placed between heated plates and edge pressure applied, in the case of a batch gluer.

The edge pressure in the continuous method is developed by a forced feed at the in-feed end and a braking action at the out-feed. The degree of pressure obtained is the result of the two forces working against each other. Top pressure is applied by the weight of the upper platen, which can be supplemented by pressure cylinders or springs when necessary.

The two greatest problems with this method are: warped and twisted stock, which does not permit intimate contact with the gluing surfaces, and precure of the glue line, due to stopping the machine for adjustments.

So that the proper cure can be obtained, it is necessary to use a resin combination that sets quickly. Usually, the pot life of this type of material is too short to be practical at room temperature, so the glue mix is cooled and the spreader is also cooled by means of a water jacket.

When the feed is stopped for machine adjustments, a number of glue lines are on the loading table and the heat coming from the press can start the glue curing before pressure is applied. When this occurs, the bond will be weak and spotty, since thick glue lines will result, without proper transfer of glue from one surface to the other.

The remedies for the above-mentioned troubles are to use stock that is flat and straight, and maintain a steady flow of stock into the machine.

A typical formulation for this work will have a pot life at room temperature of 50 to 90 minutes. The pot life can be prolonged considerably by cooling to a temperature of 50° F. The resin should be pre-cooled, then the catalyst added, otherwise the rapid action of the catalyst can start to thicken the glue mix before it has been cooled sufficiently to retard the setting action. The platen temperatures run from 300–350° F., and about 1/4-inch depth of cure should be obtained to permit moderate handling as the stock comes from the machine.

Mechanical pressure requires a better mating of components than do clamp carriers. Pressure is applied to the stock uniformly and if the stock is not straight, high localized pressures can develop on the areas that first come into contact. End-to-end bowing of the stock can produce high end pressure, which will be several times greater than that calculated for the total area. This condition results in squeezing the glue from the joints. A starved condition results, which generally produces open ends after the panels have been trimmed.

Over-dried lumber frequently produces poor bonds because of the lack of transfer of glue from the spread to the unspread edges. In extreme cases, the glue may not adhere properly to the spread areas because of a hydrophobic condition set up in the wood fibers.

In general, it is suggested that the moisture content of the stock to be edge-glued by mechanical means (to some degree in platen gluing and definitely in electronic gluing) be not less than 6 percent. This means the lumber should not be dried to less than 6 percent, since wood that has been over-dried will never regain its receptivity for proper wetting, even though the moisture content may later be raised to the proper range.

Electronic gluing introduces more factors that require attention for best results, and the characteristics to be considered are: mechanical application of pressure, chemical characteristics of the glue, electrical characteristics of the glue, and electrical characteristics of the wood.

All the problems mentioned in connection with steam-heated-platen gluing are present in electronic gluing.

The pressure on high-density species should not exceed 250 pounds per square inch to prevent starving of the glue joints. If the stock cannot be brought into intimate contact with this amount of pressure it should not be used because excessive stress will be locked into the glue line. This stress may later manifest itself in warping, checking, or open joints. To produce flat panels, the components should not be greater than 2½ inches in width.

The glue line, when heated rapidly by high frequency, thin momentarily before the chemical action starts the thickening. During this brief period of maximum fluidity, the adhesive can be squeezed from the joints, which result in over-all marginal bonds, open ends, or both, depending upon the initial points of contact made by the pieces under pressure. For this reason, thin glue mixes should be avoided when gluing high-density species.

Two methods may be used for governing the rate of set when electronic heating is used. The glue may be made highly reactive, with characteristics similar to that used in platen curing, or it may be made highly conductive, which will make the glue line heat more selectively, with less loss of power to the wood.

The mixes with increased reactivity will have short pot lives at room temperature and the disadvantage of highly acidic glue lines.

The highly conductive mixes may cause burning in the glue line, especially on certain species that will be mentioned later. It appears, then, that a compromise must be reached between reactivity and conductivity. Usually, the pot life is designed to be between 3 and 4 hours at 75° F., and in hot weather this mix may be maintained by the judicious addition of 5 percent ammonia water (approximately 1 fluid ounce to each 10 pounds of resin). The conductivity is regulated by the point at which burning occurs. The radio-frequency voltage across the electrodes and the power density in watts per square inch will dictate this point. A large generator with few glue lines in the load will produce burning, because too much power is being crowded into too little glue area.

In any event, the curing rate should not be less than 20 seconds, otherwise the glue can dry before the chemical reaction is completed. This results in an undercured glue line that has little strength and practically no water resistance. A boiled glue line will frequently be produced. Such a line is granular in appearance and brittle in nature. It feels like rough sandpaper in the open joint, and indicates too short a curing cycle, too low a moisture content in the stock, or both.

Radio frequency, in theory, heats the total glue line simultaneously and should produce uniform curing throughout its mass. In practice, however, the glue line does not heat so rapidly near the ground electrode in thick stock. This produces an uncured and frequently wet glue line near one edge of the stock when it exceeds three inches in thickness. This

can be overcome to a degree by increasing the conductivity of the glue mix, but this can be dangerous, too. The squeeze-out at the ends, being highly conductive, will encourage flash-over from the hot to the ground electrode. For all practical purposes, it is not wise to attempt heating glue lines greater than three inches.

Some wood species are prone to burning, and it is necessary to use reduced power and mixes that have a relatively low conductivity. This burning may come from mineral streaks in the wood, but generally the explanation is not that simple. It seems to be a peculiarity of mahogany, willow, cedar, and northern white pine, so low power and low-conductance glue lines should be used.

Polyvinyl Resins for High-Pressure Plastic Laminating

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THE FAST LAMINATION OF HIGH-pressure laminates to core stock is a logical extension of the use of vinyl emulsion adhesives. In joint assembly, they have become solidly entrenched because they are ready-to-use and set quickly.

In general, veneering with a high-pressure laminant is no different than veneering with wood plys. The end result is the same—a decorative material. However, the cost of a high-pressure laminant is considerably above that of even fine face veneer, and as a result a manufacturer tends to be far more critical of the appearance.

The highly reflective surface of the high-pressure laminates characteristically magnifies any defect due to the core or resulting from pressure inequalities in the pressing operation. Other than minor gluing problems, the most frequent problem that arises in high-pressure laminate gluing is "telegraphing".

The factors that influence telegraphing are: 1. core inequalities, 2. pressure distribution, 3. face strains in plastic sheet, 4. glue spread.

Core inequalities are the most obvious source of telegraphing. Species variations in lumber core, even when crossbanded and face plied, can "show through" provided the density variation is great enough. In addition, sunken joints, which have been concealed by veneering, can and do make their presence known.

How are these causes discovered? Unfortunately, a great deal lies in the realm of practical experience in uncovering the cause "on the spot". Field observation can be further checked with surface analyzers of the mechanical comparator or electronic types. In general, much information can be drawn from close visual inspection of the panels by reflected incident light. If a light is located so that its reflection appears as a ribbon across the field of vision when reflected from the polished plastic surface, the contours of the surface are revealed. The contours of the plastic surface never sharply define the core inequalities, but they will suggest the cause of the telegraphing if they approximate any of the known causes defined above. Later detailed surface analysis will generally confirm the cause of gross surface defects.

Another common cause of surface irregularity is improper pressing technique. The old method of cold-pressing veneers by means of "I" beams and turnbuckles, often used in plastic surfacing, is a common cause of trouble. Unequal pressure and localized pressure (at the "I" beam) all contribute to impressing an image or surface distortion. Laminating in a press with parallel surfaces, coupled with clean, flat cauls is the only positive cure for this condition.

One other cause of the general condition of "telegraphing", and one seldom realized by fabricators, is the mottled or "orange peel" appearance caused by face strains in the high-pressure laminate. When the face stresses are relieved by back sanding, a natural curling tendency develops. The curl is accentuated by a slight moisture pickup through the sanded side. When the sheet is forced flat in the laminating operation, stresses, induced in the face distort the melamine sheet to a minor degree over the entire face. This condition can be detected in ordinary light, but it is accentuated when viewed by polarized light.

What does all this have to do with vinyl resin? Actually very little in a direct sense. These conditions have existed for years, and it is only in the last few years that the basic reasons for their occurrence have been understood. In the plastic laminating field, the fabricator has been reasonably familiar with his core, face, and back-up material. This has not always been true where his adhesive is concerned. The various chemical types, with their accompanying variety in performance claims, have only served to cloud rather than clarify the adhesive picture. As a result, adhesives—especially relatively new types—bear far more than their fair share of complaints.

Much space has been devoted here to describing the true causes of the condition variously described as "telegraphing", "printing", "show-through", "imaging", and so forth. The causes for these occurrences are mechanical and can be minimized by material and operational changes rather than by change of adhesive procedure.

When vinyl adhesives are used for plastic laminating, a few simple rules apply. Most of them are also applicable to other adhesive types. Since vinyl adhesives are supplied ready for use, they can be drawn directly from the drum by air pump or gravity feed through a bung tap. At this point, the user should restrain the natural impulse to dilute. Synthetic adhesives have been carefully prepared and their performance can be drastically altered by the unknowing "man with the water bucket", who seeks to make his own viscosity adjustments. Ready-for-use adhesives are precise adjustments of adhesive solids, viscosity, and cure time. The qualities the user paid for can be tossed away in an instant when dilutions other than those recommended by the supplier are tried.

Equipment should be kept clean. The rate of spread (pounds/M) is governed by the condition of the spreader rolls. If these are damaged, worn, or fouled with dried adhesive, spotty or unequal spread will result. The condition will manifest itself as spotty adhesion, wasteful unequal squeeze-out, or slippage of the press load when pressure is applied.

Telegraphing caused by gross physical defects in the core cannot be overcome by changing adhesives. Neither can distortion due to poor bundling or pressing methods.

Good quality core materials are freely available. There have been some excellent, simple, low-cost presses designed for plastic laminating made available in recent years. Good cores and presses, coupled with the low pressure (20–60 psi) requirements of vinyl adhesion, can overcome most of the telegraphing problems previously described.

TENSILE STRENGTH OF

Scarf Joints in Southern Pine[1]

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Factors such as slope of scarf, wood density, matching of annual rings, and some gluing variables were studied. Scarf slope was important; specific gravity and ring matching were not. Joint strength was high, but ratios were low because of high-strength controls.

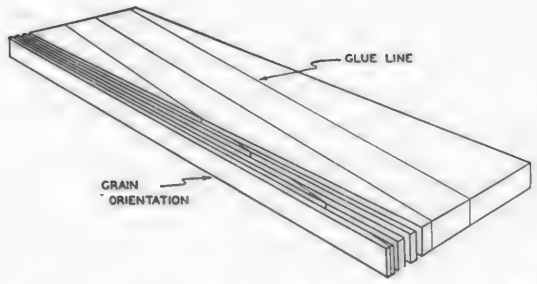

Fig. 1.—Glued up panel, showing method of orienting glue lines at the selected slope of scarf. The 3 test slats that have been ripped from the near edge of the panel are parallel to the grain.

Plain scarf joints are used extensively to end-joint individual members used in high-strength laminates. When properly cut and glued, a plain scarf joint with a relatively flat slope is, for practical purposes, the strengest end-joint now available for such use. The strength ratios allowed such joints for design purpose are usually based on a study of Douglas-fir and white oak joints published in 1946.[2] While these values have been very useful, some unpublished work by the authors as well as the work of Fox[3] in Canada had indicated that a review of this subject was needed in order to obtain more accurate strength values. The object of this experiment was to study the relationship between tensile strength of plain scarf joints in southern pine wood and such factors as slope of scarf, wood density, matching of annual rings, and certain gluing variables.

Materials and Methods

Four slopes, 1:6, 1:9, 1:12, and 1:15 were used in this study. Two resorcinol-type glues and a proved gap-filling urea-formaldehyde resin were the adhesives used in the study. Either room-temperature cure or cure at 160° F. was used on the first four panels. All remaining panels were glued at room temperature with a five-day after-cure of 100° F. The southern pine used was from kiln-dried stock that had been stored indoors under dry conditions. Although the wood used was largely loblolly pine (*Pinus taeda* L.), small amounts of shortleaf pine (*P. echinata* Mill.) and longleaf pine (*P. palustris* Mill.) may have been included.

Two or 2-½ foot lengths of 5/4-inch or thicker flat-sawn lumber were selected for straightness of grain and uniformity of growth (five or more rings per inch). Any slight diagnoal grain was removed from these pieces by wedge-shaped cuts on a jointer followed by surfacing the opposite face parallel to the straightened face. The true grain direction was then determined in the flat-sawn region of each board with a timber scriber or by marking resin ducts and drawing a line parallel to their general orientation. This true grain line was used as the reference line from which the cutting lines for the scarf joints were marked at the intended slope across the board. Cutting lines were spaced 2 inches apart for the 1:6 scarf joints, 1½ inches apart in the 1:9 scarf joints, and 1¼ inches apart in 1:12 and 1:15 scarf joints.

The boards were sawed along these cutting lines, the sawed surfaces were jointed, glue was spread, and the boards were glued back together by the use of panel clamps. When the glue had cured, the boards were dressed smooth and ripped parallel to the true grain line into thin test slats (Fig. 1). Depending on the location of the scarfed region, some slats were used to test the joint and some to test the clear wood for control purposes. A section about 2 inches long was cut from the end of each slat. This section was used for moisture content and specific gravity determinations shortly after the corresponding specimen was broken in tension.

The joints and controls were tested in tension by means of the Auburn

WHAT THIS RESEARCH MEANS

By demonstrating very high absolute tensile strength values for simple scarf joints, the authors reaffirm the high margin of safety present in laminated structures constructed with carefully manufactured scarf joints. The tensile strength of wood is shown to be so great, however, that even these strong joints do not yield the usually accepted strength ratios. Although the authors make no mention of the working stresses used for design purposes, their presentation here indicates that a review of current methods of calculating working stresses is in order. Past methods have yielded safe working stresses because the conservative assumptions have more than compensated for the liberal assumptions. Additional basic information of the type presented in this article will help the design engineer face new problems such as the current perplexing one, "Is a fingered scarf joint with a tensile strength of 12,000 psi satisfactory to use in a beam designed for a working stress of 2400 psi?"

Editor

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Forrest Goodrick attended Fresno State College, and holds a BS from API, where he is completing research for an MS in wood technology.

[1] A contributed paper, received November, 1958.

[2] Luxford, R. P., and R. H. Krone. 1946. Scarf-joints of various types in Douglas-fir and white oak compared for strength. U.S. Forest Prod. Lab. Report 1622.

[3] Fox, S. P. 1956. An investigation into the effects of certain variables in scarf-jointed timber laminations. Forest Prod. J. VI(10): 428.

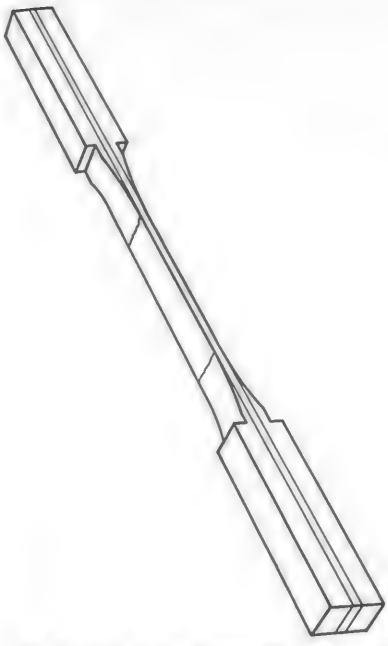

Fig. 2.—Modified tension test specimen. Hardwood grips have been glued onto the test slat and elliptical easement curves shaped in from the two opposing faces of the glued up specimen. The diagram shows a control specimen; in the scarf-jointed specimens, the joint is positioned in the central straight region of the specimen between the easement curves.

modified tension-test specimen[4] (Fig. 2). After they were tested, all specimens were carefully examined for any irregularities such as local cross grain, distorted grain, abnormal wood, and any machining defects that could have caused damaging stress concentrations. All specimens with weakening defects that might have triggered the failure were dropped from the study. Since wood in tension is extremely sensitive to defects, this stringent search for damaging defects was considered necessary to obtain a more accurate evaluation of the tensile strength of defect-free southern pine wood parallel to the grain.

[4] Richards, D. B. 1958. Simplified tension tests for wood. Forest Prod. J. VIII (1): 14.

Table 1.—ACTUAL TENSILE STRENGTH OF SCARF JOINTS AND PERCENT OF CONTROL STRENGTH AT THREE SPECIFIC GRAVITIES OF SOUTHERN PINE (ALL STRENGTH VALUES TAKEN FROM REGRESSION LINE OF EACH SLOPE)

Slope of scarf	Specific gravity[1] = 0.47		Specific gravity[1] = 0.55		Specific gravity[1] = 0.62	
	Tensile strength psi	% of Control	Tensile strength psi	% of Control	Tensile strength psi	% of Control
1:6	10,574[2]	55.8	11,682	53.8	12,651	52.4
1:9	13,844	73.1	14,751	68.0	15,545	64.4
1:12	15,285	80.7	15,691	72.3	16,046	66.5
1:15	16,511	87.2	17,620	81.2	18,592[2]	77.1
Control	18,939	100.0	21,705	100.0	24,126	100.0

[1] Specific gravity based on oven-dry weight and volume.
[2] Extrapolated value.

Table 2.—RELATIONSHIP BETWEEN TENSILE STRENGTH AND SPECIFIC GRAVITY OF SOUTHERN PINE FOR INDIVIDUAL SLOPES OF SCARF AS SHOWN BY THE LINEAR REGRESSION STATISTICS

Slope of scarf	Number of specimens N	Mean tensile strength, psi T	Mean specific gravity[1] G	Regression coefficient of T on G	Regression equation
1:6	25	11,905	0.566	13,850	T = 13,850 G + 4,0
1:9	68	14,550	0.532	11,340	T = 11,340 G + 8,5
1:12	45	15,640	0.540	5,073	T = 5,073 G + 12,9
1:15	33	17,290	0.532	13,870	T = 13,870 G + 9,9
Controls	203	21,705	0.550	34,580**	T = 34,580 G + 2,6

[1] Specific gravity based on oven-dry weight and volume.
**Significant at the 1% level of probability.

When the panels were glued together, an attempt was made to match or purposely to mis-match the summerwood portion of the annual rings of adjacent pieces. Although the intended match was not always obtained, this method did provide varying amounts of matching of annual rings between pieces. When the panels were ripped parallel to the grain line, each slat used as a joint was classified according to the degree of matching of the summerwood of the annual rings by the following arbitrary rule: perfect match, 75 per cent or greater of the summerwood matched; half-match, 25 percent to 74 percent summerwood matched; mis-match, 24 percent or less summerwood matched; cross match, match between two different pieces with rings forming a criss-cross patter at the glue line. This latter term mu not be confused with cross grain. Th cross matching was obtained by pla ing the bark side up on one side of th glue line and the pith side of a dif- ferent board up on the other side o the glue line. The wood was selecte to allow the grain line to be paralle to the long axis of the test slat as i the other matchings.

Discussion of Results

The absolute tensile strength of the plain scarf joints of average density (0.55) ranges from 11,682 psi to 17,620 psi for scarf slopes between 1:6 and 1:15 (Table 1). The strength ratios, based on controls of the same density, range from 53.8 percent to 81.2 percent. The absolute strength and strength ratios for densities 0.47 and 0.62 given in Table 1 show the values found over the approximate

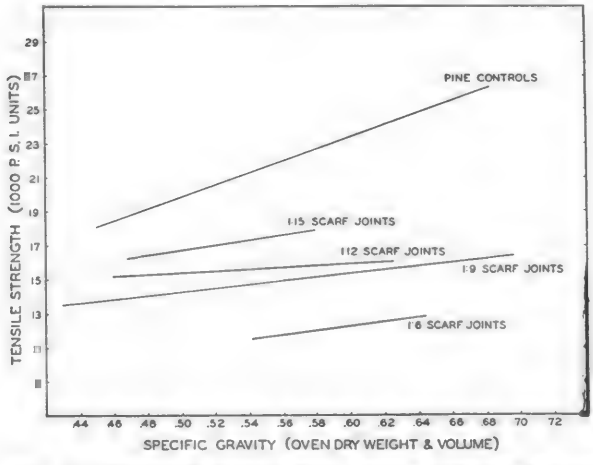

Fig. 3.—Relationship between tensile strength and specific gravity of various glued scarf joints in southern pine as shown by the least-squares regression lines. Each line spans the extreme range of specific gravity displayed by the data used in deriving the line.

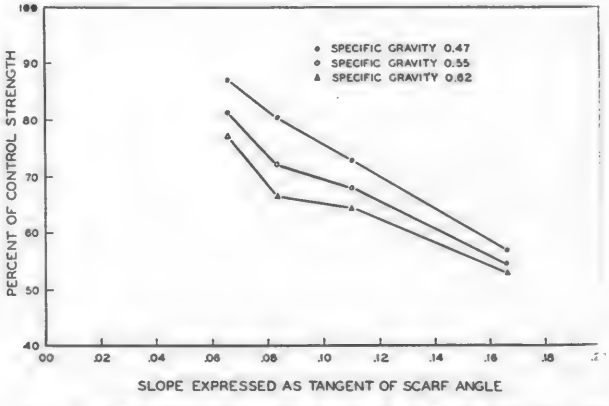
PERCENT OF CONTROL STRENGTH
SPECIFIC GRAVITY 0.47
SPECIFIC GRAVITY 0.55
SPECIFIC GRAVITY 0.62
SLOPE EXPRESSED AS TANGENT OF SCARF ANGLE

Fig. 4.—Relationship between the tensile strength of glued sca joints in southern pine and the tangent of the scarf angle. The ten sile strength is expressed as a percent of the strength of clea straight-grained controls of like specific gravity.

nge of density of the wood used in he study. Fig. 3 shows the regression nes of the controls and the four scarf opes plotted over the range of den- ty of each group.

In Fig. 4, the strength ratios for ch of the three densities presented i Table 1 are plotted over the tangent the angle of the slope of scarf. The strength ratios shown in Table 1 are lower than those published by the U. S. Forest Products Laboratory (2), even though the actual strengths of the joints are high. This, in large measure, is because of the greater control strength upon which the strength ratios in Table 1 are based.

These high control values are due to the extreme care used in selecting defect-free material for the experiment. It is believed that these strengths closely approach the actual tensile strength of southern pine.

The effect of annual ring matching was not so great as might be expected. It can be postulated that the perfect match of summerwood should be noticeably stronger than any match in which summerwood is glued to relatively weak springwood. When the strengths were plotted, no very definite pattern was observed, although the cross match seemed to fall in the lower range.

No great difference in strength due to glues or to curing temperatures was observed. It appears, therefore, that a reasonable aftercure is sufficient to develop maximum dry joint strength within the scarf slopes studied.

The regression lines of the scarf joints show a slight increase in strength with an increase in density, but because of a large variation of data this increase was found to be nonsignificant by "*t*" tests. The controls showed a significant regression coefficient by this test.

The statistical data for the study are given in Table 2. No regressions were calculated for strength on moisture content because none of the moisture content values were far enough from the average moisture content of 8½ percent to furnish any reliable trend.

Summary

Joint strength of plain scarf joints in southern pine varied markedly with slope of scarf, but showed only a slight increase in strength with increased specific gravity. Absolute joint strengths were high when compared with data in the literature, although strength ratios were low because of high-strength controls upon which these ratios were based. Little or no strength variation was associated with ring matching. High-temperature cures were not needed to develop normal dry strength when cold-setting urea and resorcinol-type adhesives were used.

EFFECT OF SEVERAL VARIABLES ON

Quality of Rotary-Cut Veneer

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Greatest influence of knife angle is on uniformity of veneer thickness. Nosebar compression affected veneer thickness, tightness, and smoothness. Cold cutting reduced tensile strength to less than 30% of controls.

[1] F. F. Wangaard was FAO adviser on veneer and plywood assigned to the FPRI from June to December, 1957, when this research was performed.

[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

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Ramon Saraos holds a ME degree from the Mapua Institute of Technology, Manila. He joined the FPRI in 1956, and is responsible for veneer-cutting studies.

ALTHOUGH THE IMMEDIATE PURPOSE of gathering the data reported here was the determination of the optimum combination of variables conducive to the cutting of superior veneer of Philippine white lauan *(Pentacme contorta* [Vid.] Merr. and Rolfe) and red lauan (*Shorea negrosensis* Foxw.), and as such would be of specific interest to producers and users of these particular species, there is another more general interest that should be served by this paper. This is the need for a general experimental method for evaluating the quality of veener produced under various cutting conditions such that the variability inherent in the wood itself may be minimized in effect. A further purpose was to gain information concerning the *quantitative* effects on veneer quality of known variations in such cutting conditions.

Fleischer (1)[2] has presented an excellent discussion of *qualitative* effects of veneer-cutting variables but there is very little *quantitative* information in the literature. Mention must be made in this connection of the work of Kivimaa (2), McMillin (4), and E. and L. Plath (5) on some specific aspect of veneer quality such as tightness in relation to nosebar compression or in relation to pretreatment temperature, but such data are extremely limited.

The quantitative data presented here are primarily of interest from the standpoint of the relationships (or lack of relationships) shown between specific cutting variables and specific factors used to measure veneer quality. The limited amount of material on which these results are based—at most three logs of each species, all from one locality—clearly requires a word of caution should they be assumed to be

WHAT THIS RESEARCH MEANS

The variability of wood from one log to another, or even within a single log, tends to obscure the real effects of different knife angles and nosebar settings in the peeling process. This paper suggests an experimental approach to the study of effects on veneer quality of different cutting conditions that will minimize the influence of variation in the wood itself.

Based on experimental cutting of lauan veneer in the Philippines, the quantitative effects of variations in knife angle and horizontal and vertical nosebar openings on veneer quality are shown. Such studies, extended to other species, should be helpful in determining the most satisfactory combination of lathe settings for the production of veneer of specified quality.

Editor

representative of the Philippine lauans. Both species are known to vary widely in their physical characteristics under the varying conditions of growth, particularly in the pattern of rainfall, prevailing in the Philippine Islands. Only through continuing studies of additional materials from other geographic sources will the range of species characteristics become evident.

The general approach in this research was to study the effect on veneer quality of variations in knife angle, horizontal nosebar opening, and vertical nosebar opening of the lathe (Fig. 1), and to determine the most satisfactory combination of these variables for each log. No provision was made to vary the sharpness angle of the lathe knife (21°) or either the angle (15°) or the condition of the nosebar, aside from removal of the wire edge after grinding. Most of the work reported here is concerned with the cold cutting of 1/8-inch veneer. In its later phases, however, the study was extended to include the cutting of 1/16-inch veneer and a preliminary trial to determine the effect of preheating veneer bolts in water at 160°F.

Material

Test material consisted of six 18-foot logs—three each of white and red lauan—that ranged from 25 to 33 inches in diameter. The logs were provided by the Philippine Plywood Corp. from its storage yard in Tagkawayan, Quezon. After the logs were delivered to the Forest Products Research Institute, they were stacked for air storage prior to being bucked to bolt length and peeled. As required for veneer cutting, the logs were bucked into 36- to 44-inch bolts, rounded on a lathe, and temporarily stored in a cold-water vat. Individual log averages for specific gravity (oven-dry weight and volume) ranged from 0.47 to 0.57 for the white lauan and 0.52 to 0.66 for the red lauan.

General Design of the Study

The objectives of this study were attained through the use of series of matched bolts, each series taken from a single log. The first two logs of each species yielded four 36-inch bolts for cutting 1/8-inch veneer and one for cold cutting 1/16-inch veneer. The third log of each species was reserved for the final phase of the study, and yielded two 44-inch bolts for comparison of the quality of 1/16-inch veneer obtained from a preheated bolt with that obtained by cold cutting.

Cutting 1/8-inch Veneer: In the case of the cold cutting of 1/8-inch veneer, the fourth bolt (D) was used for exploratory cutting with an arbitrarily selected combination of horizontal and vertical nosebar openings, 0.105 and 0.030 inch, respectively, to determine approximately the best knife angle (θ) in the range of 88° to 93°. This exploratory cutting also served to probe log characteristics with respect to depth of clear wood of veneering quality.

Knife angle: Following this selection of θ, bolt A was cut at five knife angles: for example, $\theta + 40'$, $\theta + 20'$, θ, $\theta - 20'$, $\theta - 40'$. Again, arbitrarily selected horizontal and vertical nosebar openings of 0.105 and 0.030 inch, respectively, were used. The choice of the knife angles to be used was dependent upon the width of the "uniform cutting" range found in Bolt D. Five angles, equally spaced over this range, were selected.

Horizontal nosebar opening: Bolt B was cut to determine the effect of varying the horizontal nosebar opening while the vertical opening was fixed at 0.030 inch and the knife angle was held constant at the optimum angle determined from Bolt A. The horizontal opening was varied as follows: 0.121, 0.113, 0.105, 0.097, and 0.089 inch, which correspond to veneer compressions of 0, 6, 12, 18, and 24 per cent, respectively.[3]

Vertical nosebar opening: Bolt C was cut to determine optimum vertical nosebar opening. The optimum knife angle to be used was determined previously, and one of the levels of compression found from Bolt B to give a specific quality of tight veneer was held constant. Constant compression was maintained by varying vertical and horizontal nosebar openings together as illustrated in the following example, in which it is assumed that veneer compression of 20 per cent is to be maintained:

Vertical nosebar opening, inch	Horizontal nosebar opening, inch
0.035	0.093
.030	.095
.025	.097
.020	.099
.015	.101

Cutting 1/16-inch Veneer Without Preheating: The remaining bolt of this series (Bolt E) was reserved for the cold cutting of 1/16-inch veneer. Two groups of experimental runs were made; in one knife angle was varied, and in the other, horizontal nosebar opening was varied.

[3] Nosebar opening for a particular degree of compression was calculated from the equation, $C = (HNB + VNB \tan 21°) \cos 21°$, in which C is the width of opening through which the veneer must pass for a particular combination of horizontal nosebar opening (HNB) and vertical nosebar opening (VNB). In this instance, C was taken as 0.124 times 1.0, 0.94, 0.88, 0.82, and 0.76, respectively. More precisely, $C = \{HNB + VNB \tan (KA - 69°)\} \cos (KA - 69°)$, but between limits of 88° and 93° for knife angle (KA) the error involved in using the approximation is less than 1 percent veneer compression.

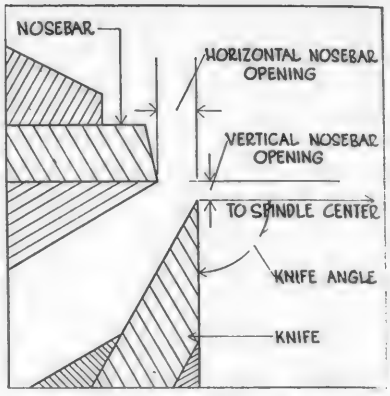

Fig. 1.—Diagram of lathe knife and nosebar, showing knife angle and horizontal and vertical nosebar openings.

In the knife-angle group,[4] five runs of veneer were cut at knife angles (the optimum angle determined in the 1/8-inch veneer series), $\alpha + 15'$, $\alpha + 30'$, $\alpha + 45'$, and $\alpha + 60'$. Horizontal and vertical nosebar openings, each reduced to one-half of the respective value in the combination found most satisfactory in the 1/8-inch veneer series, were held constant. The optimum angle β for 1/16-inch veneer was thus found. Then five additional runs were cut at angle β with nosebar compression values of 0, 6, 12, 18, and 24 per cent. Pressure was controlled by varying horizontal nosebar opening while the vertical opening was maintained constant at the optimum value.

Preliminary Cutting of Preheated Bolts: As indicated previously, the third log of each species was reserved for a preliminary study of the effects of preheating veneer bolts in hot water. This log yielded two bolts, one of which was cut into 1/16-inch veneer without pretreatment. The second bolt was preheated in a hot-water vat in which the water temperature was gradually increased to 160° F. over a 2½-hour period. After 24 hours of heating, the bolt was cut into 1/16-inch veneer. The bolt, mounted on the chucks of the lathe, was wrapped with heavy, impregnated building paper during the lathe adjustment period between runs to minimize cooling.

The cutting procedure was essentially the same as that previously described for 1/16-inch veneer. Five successive runs of veneer were cut in each of two groups—a knife-angle group and a nosebar-compression group. The knife-angle group was centered at 15 minute intervals about β, the optimum knife angle for 1/16-inch veneer found in previous cold cutting of the species. Nosebar compression was maintained

[4] This choice of angles was based upon reference in the literature (1) to a trend in the direction as veneer thickness decreased. In view of the results of this study, examination of angles both above and below α is suggested in future work.

at 12 per cent with the vertical nosebar opening held at the predetermined optimum for 1/16-inch veneer. After the optimum knife angle γ for the specified cutting condition was determined, this angle was then held constant in the nosebar-compression group, which was comparable to that previously described for 1/16-inch veneer.

Veneer-Cutting Procedure

Each bolt was considered as being made up of two zones, the outer zone extending from its rounded diameter to 19 inches and the inner from 19 to 13-inch diameter. Each of these zones was treated separately. Such division into two zones representing the outer and inner veneer-producing portions of larger logs, and the inner zone alone representing the veneer potential of smaller logs, appears to be the practical experimental limit in recognizing variation within a single log either as a result of variation in wood quality or as a consequence of log-knife geometry. (There is no implication here that veneer cutting to a core diameter less than 13 inches is impractical). Commercial lathes are often equipped with automatic pitchways that change the knife angle gradually as the cutting proceeds toward the core. In these experiments, the knife angle was not changed during the cutting but the inner and outer zones were cut independently.

Each zone yielded approximately 110 linear feet of 1/8-inch veneer or 220 linear feet of 1/16-inch veneer. In cutting 1/8-inch veneer, five 22-foot runs were made from each zone, one for each of the five conditions tested: five knife angles (Bolt A), five horizontal nosebar openings (Bolt B), five vertical nosebar openings (Bolt C). In the case of 1/16-inch veneer, two groups of five runs were made from each zone. The variables were selected in random order. In the case of knife angle (Bolt A), for example, a typical sequence of angles might have been $\theta - 40'$, $\theta + 20'$, θ, $\theta + 40'$, and $\theta - 20'$.

The veneer-cutting procedure was to operate a Coe 56-inch lathe at a peripheral speed of 100 feet per minute for a 22-foot run of veneer[5] at a particular setting. The veneer was borne off the lathe by hand and laid flat on the clipper table. The resulting sheet of veneer was clipped to yield two thickness samples (12 by 10 inches), two smoothness samples (12 by 10 inches), two tightness samples (6 by 10 inches), and two tension samples (6 by 10 inches) from each of three positions in the run: 13 to 16 feet, 16 to 19 feet, and 19 to 22 feet. Samples were selected uniformly to represent the cutting quality at the left and right ends of the lathe knife, with allowance for 2-inch spur trim at each end of the bolt.

[5] Experimental use of this procedure has shown that, in the log sizes used, the minimum veneer run to attain a sampling of representative veneer may be as much as 25 ft. in some cases. Trial cutting of bolt D can be used to establish such limits and, if log size permits, requires only minor modification of this procedure.

Fig. 2.—Loose-cut (right) and tight-cut red lauan veneer assembled into laminated specimens and scarfed for measurement of depth of lathe checks.

Methods of Evaluation

Quality of veneer was evaluated in terms of thickness, smoothness, and tightness of cut.

Thickness: Thickness specimens were stored in green planer chips and sawdust for 24 hours to permit recovery from possible temporary compression effects. Twelve measurements of thickness to the nearest 0.01 mm. (0.0004 inch) were taken with a machinist's micrometer on each specimen. Measurements were made at approximately 2-inch intervals at each of 6 points along two lines drawn across the grain. This involved a total of 72 thickness measurements on each run of veneer representing a particular cutting condition.

Smoothness: Smoothness specimens were thoroughly air dried before they were evaluated by means of the shadow-sectioning instrument described by Lutz (3). Three readings of depth of surface roughness to the nearest 0.001 inch were taken on each specimen at predetermined positions on the closed face, which appeared to represent the roughest portions of the sample. Consequently, 18 smoothness measurements were made on each run of veneer.

Tightness: Tightness of veneer was evaluated by two independent techniques: by direct measurement of depth of lathe checks, and by determination of tensile strength perpendicular to the grain.

Depth of lathe checks: The tightness samples were given a brush application of a black water-soluble dye (China ink) on the open face while still in the green condition. Following this treatment they were air dried and laminated in sets, closed face of each ply uppermost, with a cold-setting urea resin to form a composite specimen 1/2-inch thick. After several days of conditioning in the laboratory, the laminated specimen was screw-mounted on a specially prepared wedge block and machined on a planer to expose a plain-scarfed surface with a slope of approximately 1 in 12. Two such specimens are shown in Fig. 2.

Penetration of the dye quite clearly defined the individual lathe checks. From each open face adjacent to a glue line in this specimen, depth of the deepest lathe check in each of three separate areas one inch wide was measured on the scarfed surface. Thickness of the veneer as viewed on the scarfed surface was also measured, and each check-depth value was expressed as a percentage of veneer thickness. Each run of veneer was represented by 18 measurements of depth of check.

Tensile strength across the grain: Each tension sample was sawed into six tension-test specimens 1 by 6 inches. The 6-inch dimension was that perpendicular to the grain and corresponded to the direction of applied load in testing. Tension specimens were measured in width and thickness to 0.001 inch and tested as described by Kivimaa (2). A head speed of 0.025 inch per minute was used in a universal testing machine in which load could be read to 0.1 pound. Load

at failure was converted to tensile strength in pounds per square inch. Thirty-six tensile-strength values were computed for each veneer run.

Tension specimens of the same size were also prepared by sawing and planing to be used as solid-wood control specimens. Material for these specimens was provided by an 8-inch cross-sectional disk taken from each log between the third and fourth veneer bolts. Forty-eight tangentially-cut control specimens, 24 from the outer zone and 24 from the inner zone of the disk, were tested in tension by the same procedure used with veneer specimens.

Results

Cutting ⅛-inch Veneer:

Effect of knife angle: The most significant effect of knife angle on veneer quality was shown in terms of uniformity of green-veneer thickness.

A typical pattern of variation in uniformity of thickness with changing knife angle as found by the method used in the exploratory analysis of a Bolt D is shown in the following data obtained in cutting white lauan veneer. Samples were taken at several positions along the length of the veneer run, and thickness was measured at a number of points on each sample as previously described.

Knife angle, degrees	Thickness, inch: Over-all scatter	Thickness, inch: Scatter between sample averages
88	0.056	0.032
89	.024	.014
90	.009	.005
91	.008	.004
92	.011	.003
93	0.11[1]	.004

[1]Visual inspection revealed slightly corrugated veneer at 93°.

Over-all scatter refers to the difference between maximum and minimum thickness as determined by individual measurements taken throughout the run of veneer. Scatter between sample averages denotes a general variation in thickness from position to position lengthwise throughout the run.

The foregoing data conform to the recognized general relationship between knife angle and veneer thickness. At both extremes, the over-all scatter in thickness is greater than that in an intermediate cutting range. At angles below the range of uniform cutting, scatter is largely the result of long waves of irregular thickness, a condition commonly designated as "thick and thin", and appears as scatter between samples. At the higher angles, the increased scatter is associated with increased surface roughness due to tearing and, in the extreme case, to knife chatter, which results in corrugated veneer. For this illustrative bolt, a so-called "uniform cutting" range of approximately 90° to 92° is indicated. If there is a well-defined optimum cutting angle, it should occur within these limits.

The relationship between knife angle and uniformity of green-veneer thickness within an approximate "uniform cutting" range previously determined for each log is shown in Table 1. Uniformity of thickness is expressed as the standard deviation about mean thickness for each knife angle. Standard deviation was calculated from individual micrometer thickness measurements, and consequently depicts the range of thickness variation among single measurements taken throughout the run of veneer. (The 95 per cent range of variation can be readily determined as the mean ± 2 x standard deviation; hence a standard deviation of 0.0010 inch denotes a range of ± 0.0020 inch about the average thickness).

Most of the thickness values in Table 1 are based on cutting at 12 per cent nosebar compression. However, when no significant difference could be established by "t" test between values for standard deviation at 6, 12, and 18 per cent nosebar compression, these values were also included. The most satisfactory cutting range of knife angle for each zone of each log

Table 1.—RELATIONSHIP BETWEEN KNIFE ANGLE AND QUALITY OF NOMINAL ⅛-IN. WHITE AND RED LAUAN VENEER[1,2]

	White lauan				Red lauan			
		Thickness Uniformity	Smoothness	Tightness		Thickness Uniformity	Smoothness	Tightness
	Knife angle	Standard deviation about mean thickness[3] (green) in.	Depth of roughness (air dry) in.	Depth of lathe check (green) percent	Knife angle	Standard deviation about mean thickness[3] (green) in.	Depth of roughness (air dry) in.	Depth of lathe check (green) percent
Log 1								
Outer zone	88°30′	0.0031	0.0084	21.5	89°	0.0015	0.0089	54.8
	89°	.0017	.0113	31.3	89°45′	.0014 (4)	.0100	69.5
	89°30′	.0014	.0130	39.3	90°30′	.0014	.0113	75.7
	90°	.0011 (4)	.0113	55.9	91°15′	.0014	.0092	48.0
	90°30′	.0010	.0130	32.2	Average	0.00141	0.0098	62.0
	Average	0.00121	0.0121	39.7	92°	.0014	.0133	75.2
Inner zone	89°	0.0037	0.0093	29.3	89°	0.0018	0.0118	53.6
	89°30′	.0025	.0116	34.4	89°30′	.0012	.0090	55.5
	90°	.0015 (2)	.0116	43.8	90°	.0016 (4)	.0099	51.7
	90°30′	.0016	.0125	47.2	Average	0.00157	0.0102	53.6
	91°	.0010 (3)	.0113	42.5	90°30′	.0023	.0148	53.1
	Average	0.00127	0.0118	44.5	91°	.0021	.0113	55.0
Log 2								
Outer zone	89°30′	0.0025	0.0138	35.1	89°30′	0.0006	0.0102	67.6
	90°	.0014	.0133	55.8	90°	.0018 (3)		
	90°30′	.0015	.0143	57.0	90°15′	.0009	.0078	67.6
	91°	.0013 (4)	.0132	56.3	91°	.0012	.0117	71.8
	Average	0.00135	0.0136	56.4	91°45′	.0006	.0112	48.6
	91°30′	.0029	.0156	61.7	92°30′	.0011	.0110	76.4
					Average	0.00122	0.0104	66.4
Inner zone	90°	0.0017 (3)	0.0133	56.1	89°	0.0006	0.0068	58.6
	90°30′	.0018	.0140	52.7	89°45′	.0014 (4)	.0111	71.1
	91°	.0014 (2)	.0122	51.8	90°30′	.0009	.0120	71.6
	Average	0.00162	0.0132	53.5	91°15′	.0007	.0104	71.3
	91°30′	.0016[4]	.0131	60.2	92°	.0015	.0093	61.0
	92°	.0018	.0121	60.5	Average	0.00116	0.0099	66.7

[1]Nosebar compression at 12 percent with vertical nosebar opening at 0.030 in. maintained throughout, except as noted in footnote 3.
[2]Data enclosed between horizontal lines are within the optimum cutting range.
[3]Some values shown in this column represent averages for 6, 12, and 18 percent nosebar compression. When such is the case, the number in parentheses following the value for standard deviation indicates its relative weight.
[4]Veneer was visibly corrugated.

is defined by enclosing lines in the table. Optimum cutting-range limits were established primarily by excluding knife angles characterized by standard deviation values in excess of 0.0020 inch but were in some cases influenced by smoothness data as well as visual evidence of slightly corrugated veneer.

For a particular quality of wood (characteristic of a zone within an individual log), it is evident that the optimum cutting range varies in width from 1° to 3°. In general, the red lauan tested here was characterized by a wider spread of knife angle within an optimum cutting range than was the white lauan. So far as knife angle is concerned, the average standard deviation for the optimum cutting range shown in the table is the best expression for uniformity of thickness under optimum cutting conditions. Such values show that both species produced 1/8-inch veneer within a green-thickness range at the 95 per cent probability level of ± 0.0032 inch. It may also be observed from Table 1 that a 90° to 90°30′ range of knife angle satisfied the cutting requirements of both outer and inner zones of both logs of white lauan, whereas a range of 89°30′ to 90° similarly met the requirements of the red lauan tested here. The 90° knife angle satisfied the requirements of both zones of all four logs.

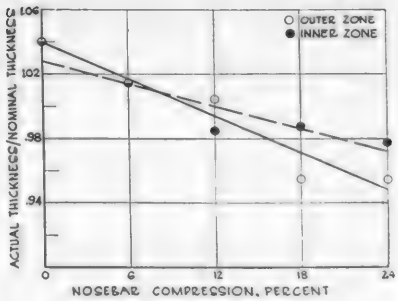

Fig. 3.—Relationship of nosebar compression to green thickness of nominal 1/8 inch white lauan veneer.

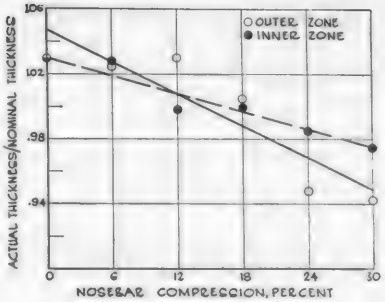

Fig. 4.—Relationship of nosebar compression to tightness of nominal 1/8 inch red lauan veneer.

Further effects of knife angle on the quality of white and red lauan veneer are given in the remaining columns of Table 1. Within the optimum cutting-range limits already discussed, neither veneer smoothness nor veneer tightness showed any significant trend with variation in knife angle. Consequently, the values that best depict the quality of veneer cut within the optimum cutting range are the average values shown for smoothness and depth of lathe check. The latter is expressed as a percentage of veneer thickness. The red lauan tested appears to have produced a slightly smoother veneer than the white lauan.

Table. 2.—RELATIONSHIP BETWEEN NOSEBAR COMPRESSION AND QUALITY OF NOMINAL 1/8-IN. WHITE AND RED LAUAN VENEER[1]

	Knife angle	Horizontal nosebar opening in.	Nosebar compression percent	Average veneer thickness (green) in.	Standard deviation about av. green thickness in.	Depth of lathe check percent	Tensile strength across grain (green) psi	Smoothness Average depth of roughness (air dry) in.
White lauan								
Log 1								
Outer zone	90°	0.121	0	0.128	0.0021	81.8	26	0.0199
	90°	.113	6	.126	.0012	69.2	42	.0150
	90°	.105	12	.127	.0009	64.0	42	.0160
	90°	.097	18	.119	.0014	51.9	74	.0136
	90°	.089	24	.119	.0021	30.8	101	.0123
						Control	487	
Inner zone	91°	0.121	0	0.129	0.0029	71.0	37	0.0199
	91°	.113	6	.126	.0008	66.8	76	.0167
	91°	.105	12	.124	.0009	49.2	77	.0136
	90°	.097	18	.124	.0012	33.4	124	.0113
	90°	.089	24	.122	.0015	25.3	139	.0110
						Control	450	
Log 2								
Outer zone	91°	0.121	0	0.130	0.0029	72.2	34	0.0186
	91°	.113	6	.126	.0013	72.4	52	.0148
	91°	.105	12	.122	.0012	60.9	49	.0146
	91°	.097	18	.118	.0016	44.7	83	.0122
	91°	.089	24	.118	.0015	36.9	94	.0120
						Control	524	
Inner zone	...	0.121	0	.....	.....	.....	...	.....
	90°	.113	6	0.126	0.0013	60.4	51	0.0138
	91°	.105	12	.120	.0014	57.4	60	.0122
	90°	.097	18	.121	.0014	36.8	108	.0111
	91°	.089	24	.120	.0012	27.4	110	.0119
						Control	509	
Red lauan								
Log 1								
Outer zone	89°45′	0.121	0	0.125	0.0027	40.6	56	0.0113
	89°45′	.113	6	.127	.0012	52.0	68	.0113
	89°45′	.105	12	.128	.0016	53.2	54	.0103
	89°45′	.097	18	.124	.0017	32.8	83	.0086
	89°45′	.089	24	.116	.0030	26.6	78	.0091
	89°45′	.081	30	.114	.0032	19.8	137	.0096
						Control	598	
Inner zone	90°	0.121	0	0.128	0.0027	50.0	49	0.0131
	90°	.113	6	.127	.0020	43.9	70	.0126
	90°	.105	12	.125	.0020	44.1	87	.0098
	90°	.097	18	.122	.0014	27.0	95	.0089
	90°	.089	24	.122	.0021	24.8	115	.0089
	90°	.081	30	.122	.0022	13.6	175	.0088
						Control	556	
Log 2								
Outer zone	90°	0.121	0	0.130	0.0022	57.1	19	0.0119
	90°	.113	6	.127	.0015	70.8	12	.0113
	90°	.105	12	.128	.0024	69.8	12	.0131
	90°	.097	18	.125	.0014	44.7	28	.0104
	90°	.089	24	.119	.0014	39.7	25	.0111
	90°	.081	30	.120	.0015	21.4	35	.0076
						Control	668	
Inner zone	89°30′	0.121	0	0.128	0.0030	66.1	26	0.0180
	89°30′	.113	6	.128	.0024	75.6	28	.0143
	89°30′	.105	12	.122	.0010	70.8	...	.....
	89°30′	.097	18	.126	.0012	43.1	67	.0072
	89°30′	.089	24	.122	.0009	31.4	46	.0067
	89°30′	.081	30	.120	.0024	26.2	59	.0097
						Control	581	

[1]Vertical nosebar opening maintained at 0.030 in. throughout.

Effect of nosebar compression: The effects of variable nosebar compression of veneer attained by varying the horizontal opening while maintaining a constant vertical opening are shown in Table 2. Knife angle was also maintained essentially constant within the optimum cutting range for log and zone.

Green-veneer thickness decreased rather regularly with increasing nosebar compression, even though two separate effects are involved. Nominal thickness of the veneer (determined by the gear ratio of the lathe feed mechanism) was 0.124 inch. At low nosebar compression, the measured thickness was invariably greater than 0.124 inch because of the increased surface roughness and the nature of the measurements—high point to high point—made with a machinist's micrometer. At higher compression levels, the effects of compression set, which amount to as much as 5 to 6 per cent, are observed. These relationships are shown further in Figs. 3 and 4, which clearly indicate the greater compression set that occurred in the outer zone as compared with the inner zone.

Uniformity of thickness, expressed as standard deviation, was consistently poor at 0 per cent nosebar compression and, in some cases, thickness also showed a tendency toward excessive variation at the 24 and 30 per cent compression levels. No appreciable effect on uniformity of thickness was

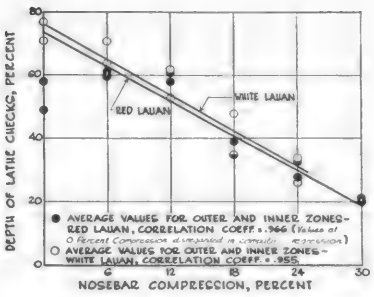
DEPTH OF LATHE CHECKS, PERCENT
NOSEBAR COMPRESSION, PERCENT
RED LAUAN
WHITE LAUAN
● AVERAGE VALUES FOR OUTER AND INNER ZONES—RED LAUAN, CORRELATION COEFF. = .966 (Values at 0 Percent Compression eliminated in computing regression)
○ AVERAGE VALUES FOR OUTER AND INNER ZONES—WHITE LAUAN, CORRELATION COEFF. = .955

Fig. 5.—Relationship of nosebar compression of tightness of nominal ⅛ inch white and red lauan veneer.

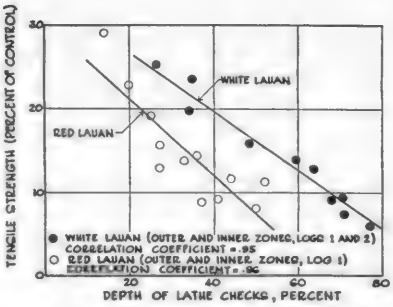
TENSILE STRENGTH (PERCENT OF CONTROL)
DEPTH OF LATHE CHECKS, PERCENT
WHITE LAUAN
RED LAUAN
● WHITE LAUAN (OUTER AND INNER ZONES, LOGS 1 AND 2) CORRELATION COEFFICIENT = .95
○ RED LAUAN (OUTER AND INNER ZONES, LOG 1) CORRELATION COEFFICIENT = .90

Fig. 6.—Relationship of tensile strength across the grain (in percent of control) to depth of lathe check for ⅛ inch white and red lauan veneer.

shown over the intermediate range of nosebar pressures.

Veneer tightness, measured in terms of depth of lathe check, was primarily influenced by nosebar compression. Depth of check ranged from 25 to 82 per cent in white lauan, and from 14 to 76 per cent in red lauan. The effect of nosebar compression on depth of checking is shown for both species in Fig. 5. In computing the regressions, average values for depth of check at each level of nosebar compression, as given for inner and outer zones in Table 2, were used. The obvious inconsistency in the data for red lauan at 0 per cent nosebar compression raises considerable doubt as to their accuracy. In view of the linear regression of depth of check on nosebar compression shown clearly in the case of white lauan, these dubious values at 0 per cent compression were disregarded in computing the regression for red lauan. The relationships shown in Fig. 5 are, for all practical purposes, the same for both species. Correlation coefficients of 0.96 for white lauan and 0.97 for red lauan indicate the high degree of dependence of depth of lathe check upon nosebar compression.

Tensile strength across the grain affords another means of measuring veneer tightness. Although highly correlated with depth of visible lathe check, this technique also permits evaluating cutting damage that may be invisible. Tensile strength values for green veneer, given in Table 2, clearly reveal the influence of nosebar compression on veneer tightness. Also included in this table are tensile strength values for the solid-wood control specimens previously discussed.

The close relationship between tensile strength and depth of lathe checks for white and red lauan veneer is shown in Fig. 6. The data for white lauan are based on both logs tested, whereas those for red lauan are based on Log no. 1 only since the variation between logs tended to obscure the relationship. Expressing tensile strength for both species as a percentage of the solid-wood control strength shows cutting damage in striking fashion. As shown in Fig. 6, the tightest veneer cut from either species retained less than 30 per cent of the strength of the original wood.

Table 2 also shows the effect of improved smoothness with increasing nosebar compression. The improvement continues at a generally slackening rate throughout the range of nosebar compression to 24 per cent.

Effect of vertical nosebar opening: Results of tests to determine the independent effect of vertical nosebar opening, with constant nosebar compression maintained, are given in Table 3. Although some differences between vertical nosebar settings appeared in one or more individual groups of tests—for one zone in one log, for example—no over-all difference in depth of lathe check was shown for either species when the data were subjected to an analysis of variance. The same was found true of standard deviation in thickness of white lauan. Although a statistically significant effect of vertical opening on standard deviation in thickness was shown by the data for red lauan, the absence of a regular trend leads one to discount the practical significance of an optimum vertical nosebar opening within the range of 0.015 and 0.030 inch when ⅛-inch veneer is being cut. The data of Table 3 are of limited value aside from providing a comparison of the several vertical nosebar openings.

Cutting 1/16-inch Veneer Without Preheating:

Effect of knife angle: Relationships between knife angle and uniformity of thickness are shown for 1/16-inch white and red lauan veneer in Table 4.

The selection of knife angles for experimental cutting requires brief explanation. In the case of Logs 1 and 2, the experimental design called for selection of five angles starting at the optimum angle α established in cutting ⅛-inch veneer from a matched bolt and increasing at regular 15-minute intervals. The discovery that optimum cutting condition could be described better in terms of an optimum cutting range rather than by a specific knife angle made the choice of α somewhat arbitrary. The procedure followed was to consider as α that knife angle within the optimum cutting range for ⅛-inch veneer which showed the least numerical value for variation in thickness and then to continue according to the experimental plan. If, as happened in cutting the outer zone of white lauan Log no. 2, this procedure produced obviously corrugated veneer, the knife-angle series was extended downward instead of upward. In the case of Log no. 3, tested later, the knife-angle group was centered about an arbitrarily selected "optimum" angle β within the optimum cutting range for 1/16-inch veneer as determined on the basis of previous cutting.

Table 3.—RELATIONSHIP BETWEEN VERTICAL NOSEBAR OPENING AND QUALITY OF NOMINAL ⅛-IN. WHITE AND RED LAUAN VENEER[1]

	White lauan				Red lauan			
	Knife angle	Vertical nosebar opening in	Standard deviation about av. green thickness in	Depth of lathe check percent	Knife angle	Vertical nosebar opening in	Standard deviation about av. green thickness in	Depth of lathe check percent
Log 1								
Outer zone	90°	0.035	0.0018	30.4	89°45′	0.035	0.0030	41.8
	90°	.030	.0011	42.2	89°45′	.030	.0010	51.8
	90°	.025	.0008	33.0	89°45′	.025	.0020	58.0
	90°	.020	.0012	38.8	89°45′	.020	.0010	56.2
	90°	.015	.0014	34.9	89°45′	.015	.0011	49.5
Inner zone	90°	0.035	0.0023	30.6	90°	0.035	0.0023	45.7
	90°	.030	.0009	39.0	90°	.030	.0016	51.4
	90°	.025	.0010	49.1	90°	.025	.0032	42.1
	90°	.020	.0013	37.1	90°	.020	.0008	30.0
	90°	.015	.0006	33.0	90°	.015	.0015	34.7
Log 2								
Outer zone	91°	0.035	0.0007	29.0	90°	0.035	0.0019	62.5
	91°	.030	.0022	43.5	90°	.030	.0029	51.3
	91°	.025	.0012	38.2	90°	.025	.0026	55.4
	91°	.020	.0010	52.8	90°	.020	.0011	54.3
	91°	.015	.0009	42.8	90°	.015	.0014	61.3
Inner zone	90°	0.035	0.0022	38.4	89°30′	0.035	0.0014	46.5
	90°	.030	.0017	50.0	89°30′	.030	.0026	41.2
	90°	.025	.0010	38.7	89°30′	.025	.0018	40.2
	90°	.020	.0012	57.2	89°30′	.020	.0012	33.0
	90°	.015	.0010	47.1	89°30′	.015	.0010	28.6

[1]Nosebar compression maintained constant for each species in this test.

Optimum uniformity in thickness as found over a knife-angle range varying from 15 minutes to 1 degree for a particular zone within an individual log. Results obtained from Log No. 3 of each species, together with the general pattern of variation, suggest that the optimum range may be wider than this, and may extend to somewhat lower knife angles than those tested here. There was no indication of an upward trend in optimum cutting angle with decrease in veneer thickness from 1/8 to 1/16 inch.

Within the optimum cutting range, the average standard deviation for white lauan varied from approximately 0.0005 to 0.0008 inch, which denotes spot to spot variation about average thickness at the 95 per cent probability level of ± 0.0010 to ± .0016 inch. Similar average standard deviations for red lauan ranged from 0.0005 to 0.0010 inch, which indicates comparable over-all variation about average thickness.

These data suggest that 1/16 inch veneer of white lauan of the qualities tested may be satisfactorily cut within a knife-angle range of 90° to 90°15′, and possibly from 89°45′ to 90°15′. A knife angle of 90° is suggested for red lauan.

Effect of nosebar compression: Table 5 reveals several relationships between nosebar compression and quality of 1/16-inch red and white lauan veneer. Decreasing thickness with increased nosebar compression, similar to that previously shown for 1/8-inch veneer, is clearly indicated in the table. Nominal thickness, determined by the gear ratio of the lathe feed, was 0.062 inch. Standard deviations about mean thickness for a specified level of nosebar compression were quite uniform throughout the 0 to 24 per cent compression range. There is some evidence of increased variability in thickness at 30 per cent compression in the data for red lauan. Veneer smoothness improved quite consistently with increasing nosebar compression.

A clear trend toward decreased depth of lathe checks with increasing nosebar compression is indicated for both species. The relationship of check depth to nosebar compression is shown graphically for both white and red lauan in Fig. 7. The graph confirms the straight-line relationship between nosebar compression and veneer tightness and reveals, in addition, that at low levels of compression the proportionate depth of lathe checks in 1/16-inch veneer is nearly as great as, and at high levels of compression somewhat greater than, that found in the case of 1/8-inch veneer (see Fig. 5).

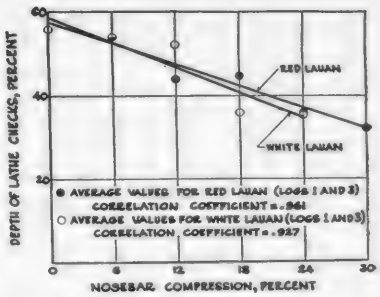
DEPTH OF LATHE CHECKS, PERCENT
NOSEBAR COMPRESSION, PERCENT
RED LAUAN
WHITE LAUAN
● AVERAGE VALUES FOR RED LAUAN (LOGS 1 AND 2)
CORRELATION COEFFICIENT = .961
○ AVERAGE VALUES FOR WHITE LAUAN (LOGS 1 AND 3)
CORRELATION COEFFICIENT = .927

Fig. 7.—Relationship of nosebar compression to tightness of nominal 1/16 inch white and red lauan veneer.

Tensile strength values across the grain for 1/16-inch veneer are also given in Table 5, but they are merely sufficient to suggest a correlation between tensile strength and depth of lathe check. Further tests will be needed to establish the relationship clearly.

Table 4.—RELATIONSHIP BETWEEN KNIFE ANGLE AND UNIFORMITY OF GREEN THICKNESS FOR 1/16-IN. WHITE AND RED LAUAN VENEER

	White lauan[1]				Red lauan[2]			
	Knife angle	Standard deviation about mean thickness[3] in.	Optimum cutting range: Knife angle	Optimum cutting range: Av. std. deviation in.	Knife angle	Standard deviation about mean thickness[3] in.	Optimum cutting range: Knife angle	Optimum cutting range: Av. std. deviation in.
Log 1								
Outer zone	90°	0.0006 (3)			89°45′	0.0009		
	90°15′	.0011	90°–90°45′	0.00068	90°	.0009 (3)	89°45′–90°	0.00090
	90°30′	.0006						
	90°45′	.0006			90°15′	.0022		
					90°30′	.0024		
	91°	.0010			90°45′	.0007		
Inner zone	90°	0.0005 (3)	90°–90°15′	.00052	90°	0.0010	90°–90°15	.00100
	90°15′	.0006			90°15′	.0010 (3)		
	90°30′	.0012			90°30′	.0012		
	90°45′	.0010			90°45′	.0012		
	91°	.0006			91°	.0012		
Log 2								
Outer zone	90°	0.0008			(Bolt was defective)			
	90°15′	.0009	90°–90°30′	.00080				
	90°30′	.0007						
	90°45′	.0013						
	91°	Corrug.						
Inner zone	90°	0.0007			(Bolt was defective)			
	90°15′	.0007						
	90°30′	.0006	90°–91°	.00058				
	90°45′	.0005						
	91°	.0004						
Log 3								
Outer zone	89°30′	0.0004			89°15′	0.0007		
	89°45′	.0004			89°30′	.0005		
	90°	.0004	89°30′–90°30′	.00045	89°45′	.0007	89°15′–90°15′	.00054
	90°15′	.0005 (4)			90°	.0005 (4)		
	90°30′	.0004			90°15′	.0004		
Inner zone	89°30′	0.0011			89°30′	0.0012		
	89°45′	.0008			89°45′	.0013		
	90°	.0008 (3)	89°45′–90°15′	.00082	90°	.0008 (4)	90°–90°15′	.00084
	90°15′	.0009			90°15′	.0010		
	90°30′	.0015			90°30′	.0011		

[1]White lauan: Nosebar compression maintained at 20 percent for Logs 1 and 2 and 12 percent for Log 3 with vertical nosebar opening of 0.0125–.015 in. except as noted in footnote 3.

[2]Red lauan: Nosebar compression maintained at 24 percent for Log 1 and at 12 percent for Log 3 with vertical nosebar opening of 0.010 in. except as noted in footnote 3.

[3]Some of the standard deviations shown are average values based on cutting of matched bolts at 18 and 24 percent compression in the case of Logs 1 and 2. Similar averages in the case of Log 3 are based on cutting at 6 and 18 percent as well as 12 percent compression. In any case the number in parentheses following the value for standard deviation indicates its relative weight.

Preheating Treatment For Veneer Bolts: This phase of the study was limited to a brief exploration of possible improvement in the quality of 1/16-inch veneer that may be attained through preheating veneer bolts in water. Results obtained in testing one bolt each of white and red lauan are given in Table 6. These bolts were end-matched with those of Log no. 3, red and white lauan, in Tables 4 and 5. Effects of variation in knife angle and nosebar compression are shown in the table. Standard deviation in thickness was relatively uniform at a satisfactory level over the entire cutting-angle range studied, thus suggesting a somewhat wider optimum cutting range than was found in cold-cutting matched bolts from the same logs. The effect of increasing nosebar compression on average veneer thickness appeared to be comparable to that shown in cold cutting.

The most striking difference between the cold-cut and preheated bolts appeared in the greater tightness of the veneer cut from the heated bolts. Expressed in terms of tensile strength across the grain, maximum tightness at 18 per cent compression was approximately doubled by preheating. The relationship between tensile strength and nosebar compression for both species is shown graphically in Fig. 8. When cut without heat treatment, both species showed a moderate increase in tensile strength (tightness) up to 24 per cent nosebar compression. The preheated bolts, in contrast, rose rapidly in tensile strength to a maximum in the neighborhood of 18 per cent compression, and had leveled or dropped off at 24 per cent. Apparently, crushing of the heated wood under a compressive strain of 24 per cent was so severe as to weaken the veneer in its subsequent resistance to tensile stress, thus counteracting any possible effect of increased tightness.

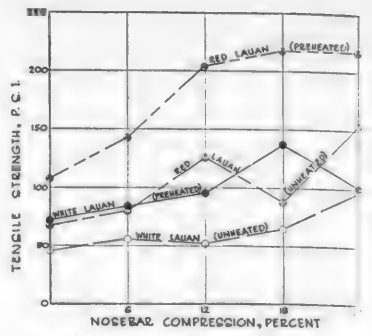

Fig. 8—Relationship of tensile strength across the grain to nosebar compression used in cutting 1/16 inch white and red lauan veneer from unheated and preheated bolts.

Summary and Conclusions

This paper, based on first results of a continuing study of the rotary veneer-cutting characteristics of Philippine white and red lauan, outlines a general experimental method for evaluating the quality of veneer produced under various cutting conditions. By systematically varying, on a series of end-matched bolts, the controllable lathe variables—knife angle, and horizontal and vertical nosebar openings—the independent effects of each of these variables on veneer quality has been determined quantitatively. From these results, conclusions may be drawn concerning the most satisfactory combination of lathe settings for the production of veneer of specified quality from logs that have characteristics similar to those tested.

Most of the work directly involved the cold-cutting of 1/8-inch veneer, but, on the basis of information gathered in such tests, the study was extended to include the cold-cutting of 1/

Table 5.—RELATIONSHIP BETWEEN NOSEBAR COMPRESSION AND QUALITY OF NOMINAL 1/16-IN. WHITE AND RED LAUAN VENEER

	Knife angle	Vertical nosebar opening in.	Horizontal nosebar opening in.	Nosebar compression percent	Average veneer thickness (green) in.	Standard deviation about av. green thickness in.	Depth of roughness (air dry) in.	Depth of lathe checks percent	Tensile strength across grain (green) p.s.i.
				White lauan					
Log 1									
Outer zone	90°	0.0125	0.0615	0	0.0642	0.0006	0.0122	48.2	25
	90°	.0125	.0575	6	.0622	.0003	.0108	51.8	82
	90°	.0125	.0535	12	.0598	.0008	.0102	39.7	83
	90°	.0125	.0495	18	.0602	.0007	.0097	35.6	106
	90°	.0125	.0455	24	.0595	.0006	.0097	33.1	110
Inner zone	90°	0.015	0.0605	0	0.0646	0.0005	0.0188	75.1	52
	90°	.015	.0565	6	.0630	.0004	.0179	50.0	98
	90°	.015	.0525	12	.0630	.0004	.0179	46.2	107
	90°	.015	.0485	18	.0626	.0004	.0171	35.7	93
	90°	.015	.0445	24	.0618	.0008	.0174	31.4	128
Log 3									
Outer zone	90°15′	0.0125	0.0615	0	0.0646	0.0009	0.0131	41.2	40
	90°15′	.0125	.0575	6	.0650	.0007	.0106	42.2	54
	90°15′	.0125	.0535	12	.0622	.0008	.0102	43.9	48
	90°15′	.0125	.0495	18	.0614	.0004	.0092	34.8	57
	90°15′	.0125	.0455	24	.0606	.0005	.0097	35.6	71
Inner zone	90°	0.0125	0.0615	0	0.0642	0.0008	0.0127	56.6	53
	90°	.0125	.0575	6	.0638	.0015	.0131	74.6	59
	90°	.0125	.0535	12	.0643	.0010	.0118	76.2	57
	90°	.0125	.0495	18	.0618	.0005	.0102	37.8	80
	90°	.0125	.0455	24	.0610	.0012	.0101	39.8	124
				Red lauan					
Log 1									
Outer zone	90°	0.010	0.0585	6	0.0649	0.0008	0.0102	59.9	88
	90°	.010	.0545	12	.0630	.0009	.0097	50.3	106
	90°	.010	.0505	18	.0590	.0010	.0083	46.6	103
	90°	.010	.0465	24	.0594	.0009	.0073	37.0	121
	90°	.010	.0425	30	.0551	.0018	.0077	29.5	123
Inner zone	90°15′	0.010	0.0585	6	0.0618	0.0005	0.0096	59.7	115
	90°15′	.010	.0545	12	.0606	.0007	.0091	53.9	159
	90°15′	.010	.0505	18	.0602	.0007	.0094	42.8	136
	90°15′	.010	.0465	24	.0583	.0014	.0087	40.6	220
	90°15′	.010	.0425	30	.0579	.0011	.0089	34.2	154
Log 3									
Outer zone	90°	0.010	0.0625	0	0.0639	0.0004	0.0117	60.2	48
	90°	.010	.0585	6	.0634	.0004	.0104	45.1	77
	90°	.010	.0545	12	.0626	.0007	.0107	33.4	86
	90°	.010	.0505	18	.0618	.0006	.0099	37.5	94
	90°	.010	.0465	24	.0594	.0007	.0089	35.8	99
Inner zone	90°	0.010	0.0625	0	0.0634	0.0008	0.0124	40.6	89
	90°	.010	.0585	6	.0634	.0010	.0114	53.1	84
	90°	.010	.0545	12	.0630	.0007	.0091	40.5	165
	90°	.010	.0505	18	.0650	.0009	.0116	53.7	81
	90°	.010	.0465	24	.0622	.0004	.0076	31.7	210

inch veneer as well as the cutting of olts pretreated in hot water.

The most significant influence of nife angle on veneer quality was its effect on uniformity of thickness. For particular quality of wood, the uniform cutting range of knife angle varied in width from 1° to 3°. A range of knife angle from 90° to 90°30′ appears to satisfy the cutting requirements of 1/8-inch veneer of the white lauan tested, whereas a range from 89°30′ to 90° meets similar requirements of the red lauan. A 90° knife angle, therefore, is within the optimum range for both species.

Nosebar compression of veneer, which involves the combined effect of horizontal and vertical nosebar openings, affected average veneer thickness, veneer tightness, and surface smoothness. Although nosebar compression in the order of 24 to 30 per cent may be required to secure the most desirable degree of tightness in cold cutting, this amount of compression may induce an undesirable compression set (crushing) in some instances. Considering both factors, the best nosebar compression for tight 1/8-inch white lauan would appear to be about 22 per cent, although reasonably tight core stock can be cut with 18 per cent nosebar compression. Similar compression limits for 1/8-inch red lauan appear to be 26 and 18 per cent, respectively.

No clear effect on veneer quality was shown by varying vertical nosebar opening in the range of 0.015 to 0.030 inch while maintaining constant nosebar compression in cutting 1/8-inch veneer.

There was no indication of the anticipated trend toward an increased knife angle for optimum cutting of 1/16-inch as compared with 1/8-inch veneer. The data also fail to indicate a need for changing the cutting angle automatically as the cutting proceeds toward the core.

Veneer of nominal 1/16-inch thickness showed effects of compression set similar to those shown by 1/8-inch veneer cut under comparable nosebar compression. Tightness of the cold-cut 1/16-inch veneer was also influenced by nosebar compression in the same general way as was 1/8-inch veneer. This was evident by visual comparison, and was confirmed by values for tensile strength across the grain.

When expressed as a percentage of values for solid-wood control specimens, tensile strength of the 1/8-inch veneer revealed cold-cutting damage in a striking fashion. The tightest veneer cut from either species retained less than 30 per cent of the strength of the original wood.

An impressive degree of improvement in the tightness of veneer obtained from bolts preheated in water at 160°F. was shown by comparison of its tensile strength with that of veneer cut without pretreatment from matched bolts. Maximum tightness was approximately doubled by preheating.

Literature Cited

1. Fleischer, H. O. 1949. Experiments in rotary veneer cutting. Proc. FPRS. III: 137.
2. Kivimaa, E. 1956. Investigating rotary veneer cutting with the aid of a tension test. Forest Prod. J. VI (7): 251.
3. Lutz, J. F. 1952. Measuring roughness of rotary-cut veneer. The Timberman 53 (5): 97.
4. McMillin, C. W. 1958. The relation of mechanical properties of wood and nosebar pressure in the production of veneer. Forest Prod. J. VIII (1): 23.
5. Plath, E., and L. Plath. 1957. Mikroskopische Untersuchungen über das Dämpfen von Rotbuche. Holz als Roh- und Werkstoff 15: 80.

Table 6.—RELATIONSHIP BETWEEN LATHE VARIABLES AND QUALITY OF NOMINAL 1/16-IN. WHITE AND RED LAUAN VENEER (VENEER BOLTS PREHEATED AT 160°F.)

	Knife angle	Vertical nosebar opening in.	Horizontal nosebar opening in.	Nosebar compression percent	Average veneer thickness (green) in.	Standard deviation about av. green thickness in.	Depth of roughness (air dry) in.	Depth of lathe checks percent	Tensile strength across grain (green) p.s.i.
				White lauan					
Log 3[1]									
Outer zone	89°30′	0.0125	0,0535	12[2]	0.0622	0.0004	------	----	
	89°45′	.0125	.0535	12	.0622	.0003	------	----	---
	90°	.0125	.0615	0	.0646	.0004	0.0115	60.6	62
	90°	.0125	.0575	6	.0654	.0006	.0118	50.8	69
	90°	.0125	.0535	12	.0630	.0000	------	----	---
	90°	.0125	.0535	12	.0642	.0004	.0102	40.6	100
	90°	.0125	.0495	18	.0614	.0004	.0092	43.2	132
	90°	.0125	.0455	24	.0606	.0006	.0095	34.3	104
	90°15′	.0125	.0535	12	.0634	.0004	------	----	---
	90°30′	.0125	.0535	12	.0626	.0003	------	----	---
Inner zone	89°30′	0.0125	0.0535	12	0.0629	0.0004	------	----	---
	89°45′	.0125	.0535	12	.0626	.0004	------	----	---
	90°	.0125	.0535	12	.0627	.0004	------	----	---
	90°15′	.0125	.0615	0	.0645	.0004	0.0111	52.4	82
	90°15′	.0125	.0575	6	.0654	.0005	.0107	42.8	100
	90°15′	.0125	.0535	12	.0629	.0002	------	----	---
	90°15′	.0125	.0535	12	.0562	.0008	.0100	48.3	92
	90°15′	.0125	.0495	18	.0633	.0003	.0091	34.3	143
	90°15′	.0125	.0455	24	.0642	.0003	.0107	36.8	98
	90°30′	.0125	.0535	12	.0624	.0003	------	----	---
				Red lauan					
Log 3									
Outer zone	89°15′	0.010	0.0545	12	0.0673	0.0007	------	----	---
	89°30′	.010	.0545	12	.0630	.0003	------	----	---
	89°45′	.010	.0545	12	.0634	.0003	------	----	---
	90°	.010	.0625	0	.0642	.0004	0.0111	49.2	110
	90°	.010	.0585	6	.0646	.0007	.0107	54.0	129
	90°	.010	.0545	12	.0630	.0002	------	----	---
	90°	.010	.0545	12	.0638	.0005	.0093	36.0	177
	90°	.010	.0505	18	.0610	.0004	.0084	31.8	226
	90°	.010	.0465	24	.0606	.0008	.0069	30.7	212
	90°15′	.010	.0545	12	.0634	.0004	------	----	---
Inner zone	89°15′	0.010	0.0545	12	0.0618	0.0004	------	----	---
	89°30′	.010	.0545	12	.0622	.0004	------	----	---
	89°45′	.010	.0625	0	.0639	.0007	0.0108	46.5	106
	89°45′	.010	.0585	6	.0638	.0005	.0097	34.5	157
	89°45′	.010	.0545	12	.0631	.0003	------	----	---
	89°45′	.010	.0545	12	.0631	.0003	.0089	32.2	232
	89°45′	.010	.0505	18	.0609	.0005	.0073	24.5	209
	89°45′	.010	.0465	24	.0603	.0011	.0066	25.4	221
	90°	.010	.0545	12	.0632	.0003	------	----	---
	90°15′	.010	.0545	12	.0622	.0005	------	----	---
	90°30′	.010	.0545	12	.0626	.0005	------	----	---

[1] All data are within the optimum cutting range.
[2] Nosebar compression values at 12% with incomplete columns are data from knife angle series.

THE NATURE AND SIGNIFICANCE OF THE

Natural Durability of Diamond Willow Heartwood[1,2]

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Willows with diamond-shaped cankers on the stem show natural durability. Toxic extracts were separated by ion-exchange and paper chromatography techniques and evaluated against wood destroying fungi.

Fig. 1.—The appearance of "diamond" cankers on a stem and cross section of *Salix eriocephela*.

Many factors have been suggested as important in contributing to the natural decay resistance of wood (1).[4] Hawley (4) was among the first to note the relationship between durability and extractives when he demonstrated the toxicity of water extractives of a number of native species. He concluded that in most cases the extractives of the highly durable woods were toxic to wood-decaying fungi. Sherrard (14) in a study of the extractives of redwood and Scheffer (13) in a study of the extractives of black locust have suggested a direct relationship between the durability of the wood and the presence of extractives. More recently, Kennedy (6) has isolated taxifolin, a phenolic flavanoid compound from an extract of Douglas-fir, and found it to be toxic to wood-rotting fungi commonly associated with this species. Freudenberg (2) has isolated robinetin, a related flavanoid, from black locust. Oberg (12) in a study of the zones of discolored wood in aspen found that regions that show fluorescence under ultraviolet light were more durable in soil-block decay tests than the nonfluorescent discolored material, and substantiated this trend with toxicity tests of the extractives from the fluorescent and non-fluorescent discolored material.

The more recent literature is extensive in reports of the application of chromatographic techniques to the separation and isolation of components from wood and other plant extractives. The theory and techniques of chromatography as well as its application to specific problems are given in monographs such as that of Lederer and Lederer (7). The work of Wender (15) has provided an excellent basis for the separation and identification of flavanoid compounds from plant extracts. Lindstedt (8, 9, 10) has separated and identified many compounds from pine heartwood extracts by chromatographic methods.

Although the several species of willow are classed as being generally non-durable (5), "diamond willow" has occasionally been observed to be remarkably durable when used as fence posts. "Diamond willow" is characterized by the appearance of diamond-shaped cankers in the stems, particularly of *Salix eriocephala* Michx., Missouri River willow, and *S. discolor* Muhl., pussy willow. It has been suggested that the presence of micro organisms that may be associated with the development of the canker may stimulate the production of compounds toxic to wood-decaying fungi and thus increase the durability of the associated heartwood.

The objectives of the present study were to evaluate the relative durability of a limited sample of the heartwoods of these two species of "diamond willow" toward selected decay fungi, and to evaluate the toxicity of the extractives from *S. eriocephala* heartwood toward these same fungi. A correlary objective was the application of partition chromatography to the isolation of individual extractive components, which may to a large degree be responsible for the observed natural durability of the wood.

Experimental

Soil Block Decay Tests: Samples of ¾ inch cubes of outer heartwood were cut from near each end of nine bolts of *S. eriocephala* to give specimens identified as to location in each of the 6-foot-long bolts. Selection of the specimens in this manner facilitated an analysis to determine differences that might exist in the decay

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[1] Based on a MS thesis at the U. of Minnesota.

[2] Paper No. 4040 in the Scientific Journal Series of the U. of Minnesota Agricultural Experiment Station.

[3] The authors gratefully acknowledge the help of Dr. D. W. French of the Div. of Plant Pathology and Botany, Inst. of Agr., U. of Minnesota.

[4] Numbers in parentheses refer to the Literature Cited at the end of this report.

Table 1.—RESULTS OF SOIL BLOCK DECAY TESTS EXPRESSED AS PERCENT WEIGHT LOSS

Block	Diamond willow isolate	*P. Tulipiferus*	*P. Versicolor*
Salix eriocephala heartwood			
	22.3	26.8	32.5
	17.9	16.1	25.5
	14.4[1]	8.9[1]	26.6[1]
	18.3	31.2	23.0
	7.2[2]	10.1[2]	20.5[2]
	11.6[2]	3.7[2]	21.8[2]
	12.5	10.3	38.7
	2.0	7.6	26.0
	5.4	7.4	28.4
1	1.3	10.9	27.9
1	12.8	14.4	45.3
1	14.8	26.9	28.0
1	2.8	5.3	17.8
1	2.5	2.3	8.5
1	6.6	10.0	26.7
1	14.8[2]	23.7[2]	24.1[2,3]
1	13.9	20.5	26.1
15	16.2	12.5[2]	23.6[2]
Averages for fungi	11.0	13.8	26.2
Over-all average		17.0	
Salix discolor heartwood			
1	26.7	43.8	23.8
2	25.7	26.3	27.1
3	35.2	34.0	36.7
4	29.8	51.1	29.4
5	31.6	18.0	23.9
Average for fungi	29.4	34.6	28.2
Over-all average		30.7	
Populus tremuloides sapwood			
1	51.4	55.1	44.1
2	72.4	44.6	43.8
3	55.1	57.4	39.6
4	57.9	60.1	29.7
5	54.1	39.4	51.0
Average for fungi	58.2	51.3	41.6
Over-all average		50.2	

[1]Decay present prior to test.
[2]Bound with stainless steel wire because of checking.
[3]Contaminated.

resistance at different heights in the stem or between bolts. Some of the specimens were checked, and decay was present in three of the specimens. These defective specimens were retained in the test, however, in the interest of proper sampling, and it was shown (Table 1) that neither irregularity affected the results of the tests.

Random samples of specimens of the outer heartwood of *S. discolor* and of *Populus tremuloides* Michx. sapwood were selected for inclusion in the tests. Both of the willow heartwood samples were taken from stems that showed the "diamond" canker.

The sample blocks were conditioned at 70°C. for 24 hours and weighed. This condition was selected in order to minimize possible destructive effects of the usual higher temperature drying schedule on sensitive components of the heartwood extractives. The results of the decay tests, although comparable within the present study, are not directly comparable with data obtained by other workers who used different conditions of oven drying. Recognition of this relationship is in part the basis for selection of aspen sapwood as the control material rather than the associated willow sapwoods. Aspen sapwood was assigned a value of unit durability, and, as discussed in a following section, the relative durability of the heartwood samples has been expressed as a ratio to that of aspen sapwood.

The decay tests were carried out in 8-ounce "French" bottles as illustrated in Fig. 2. The bottles were filled approximately half full of loam soil adjusted to 40 per cent moisture content, aspen feeder strips were added with the bottle in the horizontal position, and the units were sterilized in the autoclave at 121°C. for 30 minutes. After sterilization, the units were appropriately inoculated with one of the three test organisms: *Polyporus tulipiferus, P. versicolor,* and an unidentified isolate from decayed "diamond willow". Eleven days after inoculation of the units, the conditioned and weighed specimen blocks were surface-cleaned by a 15-second dip in boiling water and placed on the mycelium-covered feeder strips.

Eighteen specimens, one from the top end and one from the bottom of each of the nine bolts of *S. eriocephala,* five specimens of *S. discolor* heartwood, and five specimens of aspen sapwood were assigned to each of the fungi. The loosely capped culture bottles were placed in an incubation cabinet for a period of 90 days at a temperature of 23 to 30°C. and a relative humidity of 70–83 per cent. At the end of the test period, the specimens were removed from the bottles, brushed free of soil particles and mycelium, reconditioned at 70°C. for 24 hours, and weighed.

Preparation of Wood Extractives: A supply of *S. eriocephala* heartwood was excised from the narrow band of sapwood, reduced in a laboratory hammer mill, and air dried. The excised sapwood was treated in the same manner. In a typical preparation, 300 grams of the air-dried heartwood was extracted with two successive three-liter portions of distilled water at 70 to 80°C. with frequent stirring during a period of eight hours. The extract was removed by vacuum filtration before addition of the second portion of fresh solvent. The final residue was exhaustively washed on the filter with

WHAT THIS RESEARCH MEANS

In the past, the terms 'most durable', 'moderately durable', and 'least durable' have been used to describe the natural decay resistance of various woods. This paper suggests a method based on a standard control that would give a basis for representing the relative durabiilty of different species.

The research in chromatographic separation of wood extractives serves to provide basic information for the separation of these materials, particularly those extractives in the species of willow studied.

Editor

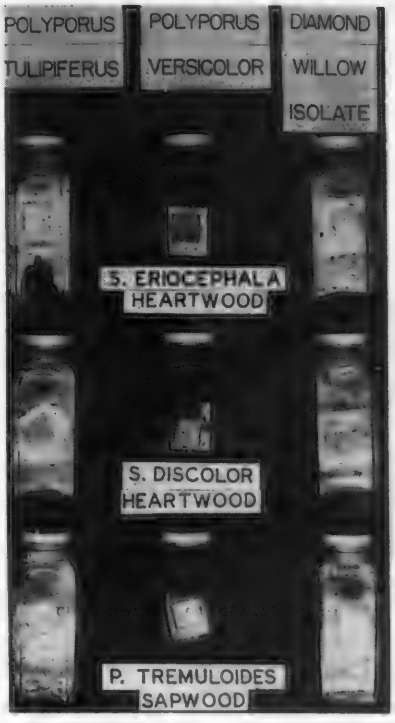

Fig. 2.—Growth of typical cultures at completion of the soil block decay test.

boiling distilled water and air dried. The dried residue was then exhaustively extracted with 95% ethyl alcohol in a Corning Glass Works No. 3885 modified Soxhlet extractor.

The resulting extractive solutions were reduced as required to a convenient volume by vacuum distillation. The alcohol extracts were distilled in small portions in order to prevent the accumulation of tars that appeared after prolonged heating, even at the relatively low temperatures encountered. A small quantity of precipitate that formed during the distillation of the alcohol extracts of the heartwood was filtered, recrystallized from alcohol, (m.p. 73–76°C. uncorr.) and later shown to correspond to component 12 of the chromatogram of Fig. 3.

Separation of Extractive Components: A gross separation of the crude alcoholic heartwood extract was attempted with a column of Amberlite IRA-400 (Rohm and Hass) strongly basic ion-exchange resin. The resin was regenerated to the OH-form with aqueous NaOH followed by exhaustive washing with distilled water and replacement of the water with 95% alcohol. Two liters of fresh alcoholic heartwood extract was passed through the column followed by a wash of fresh alcohol. The column was then stripped of absorbed material by elution with a 10% solution of HCl in 95% alcohol. The acid eluate was neutralized with $BaCO_3$ and distilled under vac-

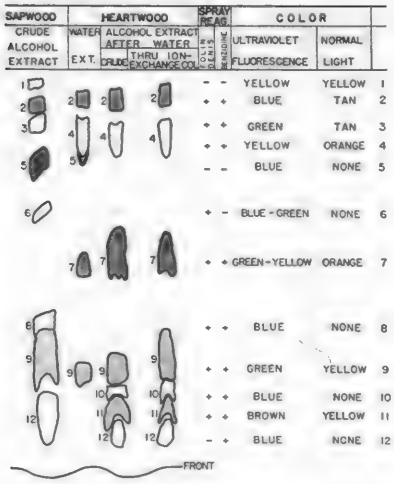

Fig. 3.—Diagrammatic reproduction of chromatograms of extracts from *Salix eriocephala*.

uum to give a small quantity of dark-colored, viscous residue.

Although agar plate tests showed this material to be significantly toxic, the difficulties encountered in attempts at further resolution led to abandonment of the technique in favor of partition chromatography of the crude extracts. The components of the extract that were removed by the ion-exchange resin were found to appear as a series of difficult-to-resolve spots in the region between the origin and component 2 of the chromatogram given in Fig. 3.

Partition Chromatography of Extractive Components: The procedure for paper partition chromatography followed that given by Oberg (11) except in the use of indicator spray reagents. The stock solution of Folin and Denis reagent as prepared by Gortner (3) was first diluted with an equal volume of water before it was sprayed on the dried chromatogram. The freshly sprayed chromatogram was then hung in a chamber saturated with ammonium hydroxide vapor. Use of the diluted reagent led to the development of more clearly defined blue to black spots with less interference from background color. "Benzidine reagent", a specific color reagent for phenolic compounds, was prepared and applied to freshly developed and dried chromatograms as described by Lindstedt (9). Spots that gave a positive reaction appeared in colors ranging from deep red to blue.

Cellulose column elution chromatography was used for the isolation, in pure form, of macro quantities of at least one of the components of the extractives that appeared in the paper chromatograms. Standard grade Whatman cellulose powder was suspended in three successive portions of an excess of 2% aqueous Na_2CO_3 followed by suspension in three successive portions of an excess of acetone. The material was filtered with vacuum between each treatment, and was finally spread out to allow the absorbed acetone to evaporate completely.

The dried powder was resuspended in four successive portions of an excess of secondary butyl alcohol, which had been previously equilibrated in a separatory funnel with a 2% solution of aqueous Na_2CO_3. The final suspension was poured into a Pyrex column (2.6 by 93 cm.) fitted at the top with a 500 ml. flask as solvent reservoir and at the bottom with a stopcock for control of the flow of the eluting solvent. A slight air pressure was then applied at the top of the column, and, with the stopcock partially open, the slurry was allowed to drain and settle into a tightly packed column of material. Extreme care was necessary to insure the preparation of a uniformly dense column of packed material.

The solvent used in the development and elution of the chromatograms was again secondary butyl alcohol equilibrated with 2% aqueous Na_2CO_3. The crude extractive, previously taken to dryness, was taken up in a minimum of the eluting solvent, heated over a steam bath to insure complete solution, slightly cooled, and poured onto the top of the cellulose column. The progress of the eluting bands as illustrated in Fig. 4 was followed by their fluorescence under ultraviolet light by means of either an Hanovia No. SC–5041 lamp or a 40-watt "BLB" black-light tube for irradiation. It was found that, if the elution of the column was interrupted for an extended period of time, the position and intensity of the bands remained constant until elution was resumed.

In a typical experiment, three liters of solvent flowing at the rate of 32 drops per minute during a period of 20 to 30 hours was required for the elution of 5.5 gm. of extract from an 80 cm. column. Aliquots of eluate were collected in successive 25 ml. portions with 80 per cent recovery of the material originally placed on the column. One and seven tenths grams (1.7 gm.) of chromatographically pure product (30 per cent of the crude extractive or 1.6 per cent of the original air-dry heartwood) were collected as fraction No. 2 in order of elution from the column. A paper chromatogram of this product showed that it corresponded to component number 7 of Fig. 3, with an Rf value of 0.53. This material was tested for its fungal toxicity.

Agar Plate Toxicity Tests: The alcohol extracts were taken to dryness,

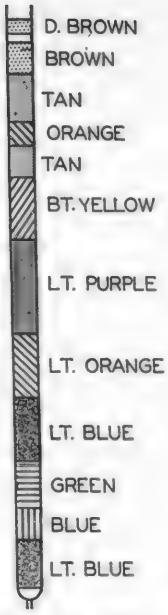

Fig. 4.—Diagram of cellulose column chromatogram of the alcohol extract of *S. eriocephala* as observed under irradiation with ultraviolet light. The colors represent fluorescent bands of individual components which appear in the same order as in the paper chromatogram of Fig. 3.

weighed, and re-dissolved in a measured volume of acetone. The resulting solutions were added proportionately to flasks of hot, freshly prepared and sterilized Difco-Bacto malt agar to give media containing the designated per cent by weight of the respective extractives. Control media were prepared by the addition of corresponding volumes of acetone alone. After volatilization of the solvent, the warm media were poured into petri dishes, cooled, and inoculated with uniform circular discs of mycelium-bearing agar taken from fresh cultures of *P. tulipiferus* and *P. versicolor* as required. The water extracts were distilled under vacuum to an appropriate concentration and then added to the hot, sterilized malt agar as above to give the designated concentrations of media. Controls for the water extractives consisted of plain malt agar. The cultures were kept under protective cover of a period of 14 days with periodic radial measurement of mycelial growth.

Discussion of Results

The results of the soil-block decay tests are given in Table 1. A comparison of the over-all mean percent weight losses leads to the conclusion that, for the samples tested, *S. eriocephala* (17.0%) was more resistant to decay than *S. discolor* (30.7%), which was in turn more resistant than aspen sapwood (50.3%). An analysis of variance showed a highly significant

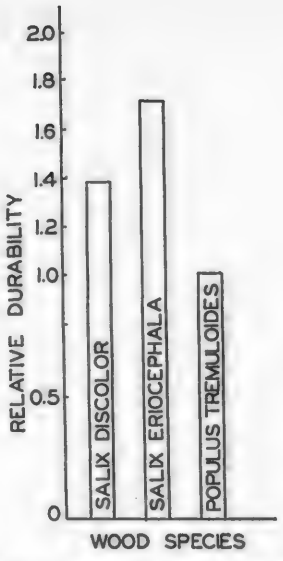

Fig. 5.—Graphical representation of the soil-block-test durability of "diamond willow" heartwoods relative to aspen sapwood.

difference in the extent to which the three fungi attacked the heartwood of *S. eriocephala.*

To describe the relative durability of the two samples of willow heartwood by another method, the sapwood of aspen was selected as a reference material and assigned a value of unit durability. The relative durability of *S. eriocephala* heartwood to that of aspen sapwood was then expressed as a ratio of the over-all mean percent by weight of residual material after completion of the test.

$$\text{Thus: } \frac{S.\ eriocephala}{\text{aspen}} = \frac{(100 - 17.0)}{(100 - 50.2)} = 1.67$$

and similarly, *S. discolor* gave a ratio of 1.39. These ratios are expressed graphically in Fig. 5. Although the use of aspen sapwood as a reference standard is subject to criticism because of inherent variability, it serves as a useful independent control within the scope of the present experiments. A comparison of the sapwood chromatogram of Fig. 3 with that of Oberg (11) for aspen sapwood prepared under identical conditions lends support to the choice of aspen as a control. The associated willow sapwood is shown to contain at least four extractive components not present in the heartwood, and at least four components that are common to both the sapwood and heartwood, whereas aspen sapwood is by comparison essentially extractive-free.

Although the range and complexity of properties of the components in wood extractives precludes the use of any single chromatographic solvent system for the complete elucidation of its composition, the system employed in the present study has proven to be remarkably versatile and definitive, as illustrated in Fig. 3. Spots representing other constituents were noted in the original chromatograms, but were not clearly definable because of faintness and masking. It may be noted that some components appear in one extract but not in another. Components 7 and 11 are of particular interest since they both appear in the extracts of heartwood but not in sapwood of *S. eriocephala,* and both react positively to the phenolic indicator reagents. A crystalline product that separated by precipitation from the crude alcoholic heartwood extract was found, when spotted on a chromatogram with the crude extract, to correspond with component 12 (Rf – 0.97).

Separation of the extractive components by cellulose column chromatography led finally to the isolation of a pure phenolic compound that amounted to 30 percent of the crude extract. This compound was shown by comparison on a paper chromatogram to correspond to component 7 of Fig. 3. An agar plate toxicity test of this compound as illustrated in Fig. 6 showed that *P. tulipiferus* was killed at a concentration of 0.5 percent by weight. Sufficient quantities of the pure compound were not available at the time of this test to permit the determination of the threshold concentration. Study of this compound is being continued, and the results will be presented in a later report.

The results of toxicity tests on the crude extractives of *S. eriocephala* heartwood are illustrated in Figs. 7, 8, and 9. It is apparent from these that the water extract was less toxic than

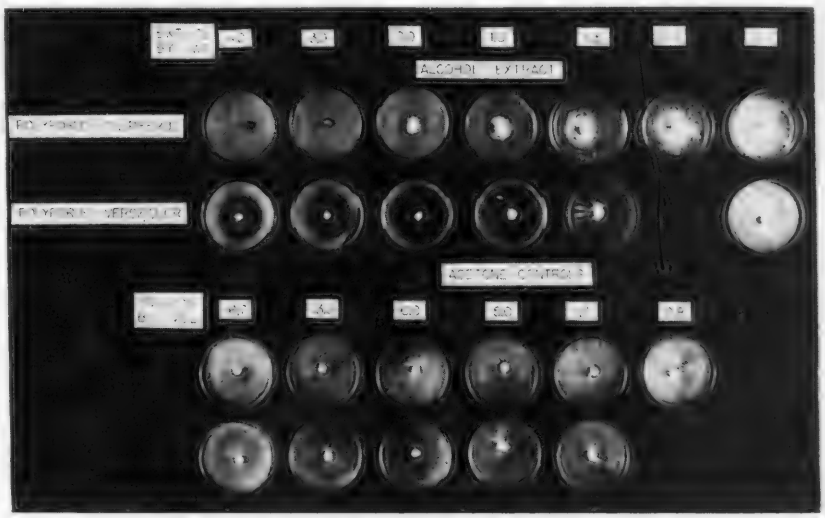

Fig. 8.—Toxicity test of the crude alcohol extractive of *Salix eriocephala* heartwood.

Fig. 7.—Toxicity test of the crude water extractive of *Salix eriocephala* heartwood.

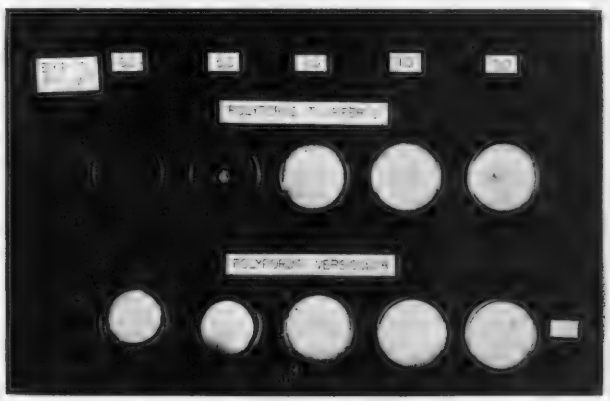

Fig. 6.—Results of a toxicity test of component 7 of Fig. 3 against *Polyporus tulipiferus.*

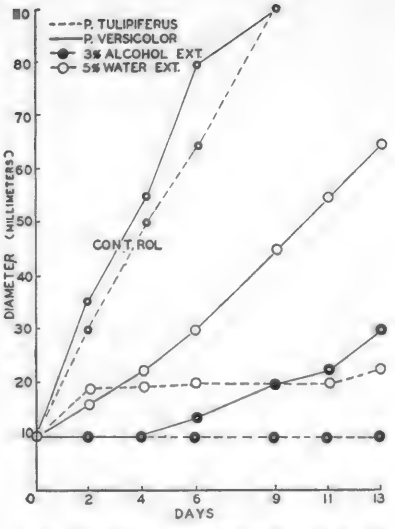

Fig. 9.—Rate of diameter growth on selected plates of the toxicity test represented in Figs. 6 and 7.

the alcohol extract. A consideration of this observation in conjunction with the chromatogram of Fig. 3 suggests several things. It is possible that one or more of the components 10, 11, and 12 that appear in the alcohol extract but not the water extract are significantly toxic and would thus explain the greater gross toxicity of the alcohol extract. Since it has been established that component 7 is toxic, the difference in toxicities of the crude extractives may be simply related to the respective concentrations of this component. At present, the authors are inclined to suggest that component 7 is the major toxic constituent of these extractives.

Literature Cited

1. Brown, H. P., A. J. Panshin, and C. C. Forsaith. 1949. Textbook of wood technology, Vol. I. McGraw-Hill Book Co. Inc., New York.
2. Freudenburg, K., and L. Hartmann. (Univ. Heidelburg, Ger.), 1955. Constituents of *Robinia pseudoacacia* heartwood. (Abs.) Chem. Abs. 49: Mar. 25 May, 5456.
3. Gortner, R. A. and E. C. Holm. 1920. The colorimetric estimation of tyrosine by the method of Folin and Denis. J. Amer. Chem. Soc. 42: 1678.
4. Hawley, L. F., L. C. Fleck, and C. A. Richards. 1924. The relation between durability and chemical components in woods. Ind. Eng. Chem. 16: 699.
5. Hunt, G. M., and G. A. Garratt. 1953. Wood preservation, McGraw-Hill Book Co. Inc., New York.
6. Kennedy, R. W. 1956. Fungicidal toxicity of certain extraneous components of Douglas-fir heartwood. Forest Prod. J. VI (2): 80.
7. Lederer, E., and M. Lederer. 1953. Chromatography. Elsevier Publishing Co., New York.
8. Lindstedt, G. 1950. Constituents of pine heartwood. Acta Chem. Scand. 3: 763, 767, 770, 1147, 1375, and 1381.
9. Lindstedt, G. 1951. Separation of phenolic heartwood constituents by paper partition chromatography. Acta Chem. Scand. 4: 448.
10. Lindstedt, G. 1952. Constituents of pine heartwood. Acta. Chem. Scand. 5: 129.
11. Oberg, J. C., R. L. Hossfeld, and F. A. Kaufert, 1956. Fluorescent materials associated with discoloration in aspen. TAPPI 39: No. 7, 470.
12. Oberg, J. C., R. L. Hossfeld, and D. W. French. 1957. The appearance and decay resistance of discolored aspen. Forest Prod. J. VII (10): 378
13. Scheffer, T. C., H. G. Lachmund, and H. Hopp. 1944. Relation between hot-water extractives and decay resistance of black locust wood. J. Agr. Res. 68: 415.
14. Sherrard, E. C., and E. F. Kurth. 19 . The distribution of extractive in wood: its relation to durability. Forest Prod. Lab. Report 988.
15. Wender, S. H., T. B. Gage, and C. D. Douglass. 1951. Identification of flavanoid compounds by filter paper chromatography. Anal. Chem. 23: 15 2.

A STATISTICAL PLANNING SYSTEM FOR

Control of Logging Operations[1]

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Because of the intangibles involved, planning and control of logging operations are very difficult. In the system described, the elements of a work cycle and influencing variables are first determined. Time-study data are then collected by a reliable sampling scheme and analyzed statistically. A control system based on a mathematical model is then established.

FOREST OPERATIONS RESEARCH, usually called FOR, is a scientific method by which management problems of forest exploitation are defined and solved in an optimum manner. Its techniques enable woodlands managers to analyze and weigh all factors involved in a given logging system and to arrive at the best possible decisions.

Why is FOR Necessary in Logging?

It is the necessity that justifies the application of scientific methods to logging. Because of the numerous factors and intangibles involved in forest work, logging problems are extremely complex and difficult to define. Actually, most logging problems are generally solved on the basis of personal experience only. The main objective of FOR is, thus, to offer some principles that will permit woodlands managers to get free from empirical methods and optimize their decisions in regard to planning and control of logging operations.

FOR borrows its techniques from operating research, a science developed during World War II and used for planning military operations. There is a great similarity between military and logging operations:

1. Both are outside activities.
2. Both are influenced by a large number of variables and intangibles.
3. Logging engineers, as well as army officers, never face the same situation twice.
4. In both cases, decisions must be made quickly.
5. Both are spread over a large area.

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This similarity explains why the logging industry can borrow heavily from military operations research activities.

Problems Solved by FOR: FOR can be used to solve a wide variety of problems. The main ones are: Production and cost control, machinery replacement, production planning, inventory control, labor training techniques, work methods analysis, allocation of equipment to various work places, logging layouts, and so forth. Indeed, almost all executive problems of forest exploitation could be tackled by FOR techniques.

One contribution FOR made to the logging industry is the establishment of a production planning and control system. The following is a brief picture of its construction, way of application, and results obtained so far.

Objectives of the system: The system has been designed to meet the following objectives:

a) Planning logging operations.
b) Controlling production and costs.
c) Determining the best work methods in relation to conditions of the work sites.
d) Establishing labor training programs.
e) Finding training needs.
f) Detecting best tools, equipment, and workers.
g) Finding optimum factors of production.
h) Establishing a wage scale in relation to difficulties of the work sites.

Logging Principles: The search for a planning and control system applied to logging requires first a thorough study of the operations themselves. To solve his problems, the logging engineer must know, above all, the basic principles that govern the forest work. Obviously, the principles of forest exploitation cannot be as rigorous as those of physics. However, approximations are perfectly satisfactory as long as the probable deviation between the result foreseen by the principles and the actual result is known.

Methodology of Production Control in Logging

The law, principle, or mathematical model, is established from the observation of the operations. The whole work cycle is subdivided into its fundamental phases, each one of them is timed, and variables that influence the performance are recorded. Through the application of a sound sampling scheme, a mass of data is thus collected. This information is then compiled and analyzed on the basis of statistical principles. Finally, the mathematical model is derived and control limits, within which actual performance may deviate by chance alone, are established. This model and its variance are then ready to be used for planning and control purposes.

To clarify this brief summary on model construction, an example is taken. Suppose you are asked to define the principle governing pulpwood transportation with a tractor. The procedure to derive the model would be as follows:

Preliminary Observation: If nothing is known about the tractor hauling operation, the first thing to do is, of course, to go in the field and observe it for some time. From this preliminary observation, the main phases of a work cycle (a round trip) will be determined. These phases could be, for example, pulpwood loading, hauling, unloading, and return of the machine to the loading point.

The main variables that seem to influence each phase of the cycle are then established. They may be the wood volume, the hauling distance, the topography, the number of logs per unit volume, and so forth. At this point of the study, these variables are only plausible explanations of the facts, which must be verified through further experimentation.

Finally, the statistical unit, which is the precise definition of the nature of the observed phase, is chosen on the basis of the hypothetical variables. It may be the man-minutes per cord, the machine-minutes per 100 feet of hauling distance, or something of this nature.

Work Analysis: Once a good experimental knowledge of the work performed has been acquired, the next step in model construction is to carry out a work analysis. The objective of a work analysis is to detect, and, if possible, remove all unnecessary delays, to correct bad work habits, and to improve the equipment used. Motion-economy principles, statistical-control techniques, personal experience, imagination, and judgment are at the basis of good work analysis. Results obtained during this phase of model construction are usually very rewarding. For example, last year, pulpwood loading time was decreased by 87 percent as a result of a work analysis..

Sampling Scheme: The following work analysis is the preparation of a reliable sampling scheme. The purpose of the scheme is to obtain a representative sample of the work studied so as to arrive at the best possible estimate of the model of the whole population (for example, all trips made during one hauling season).

In preparing the sampling scheme, attention must be given to the following points:

a) the size of the sample,
b) the manner in which the observations are to be obtained,
c) the workers who should be observed,
d) the moment at which sampling should be stopped.

The sampling scheme, of course, is prepared according to statistical principles.

Collecting Data: The next step is to collect the necessary information in the field. Special forms have to be prepared, the timing method must be described, and time-study men are chosen and trained. The timing period continues until conditions set forth in the sampling scheme are fulfilled. One of the most important of these conditions is statistical stability of the data. Stability exists when information obtained obeys the laws of chance. In other words, a set of data is said to be stable when it follows random variation and stays inside control limits determined during the sampling period.

Analysis of Data: The final stage of model construction is to submit the mass of data to a thorough statistical analysis. The main steps involved are the preparation of frequency distributions for each phase of the work cycle, investigation of statistical stability, rejection of abnormal data, test of normality and symmetry of distribution, transformation of variables to "normalize" the population, and finally the derivation of the mathematical model and its variance through a statistical or functional relationship analysis. It would be outside the scope of this paper to explain these steps in detail.

The following equation for a self-loading tractor is an example of a mathematical model as derived from the analytical procedure previously summarized.

$$T_E = 4.26 + .46\ D_H + .42\ D_R$$

where T_E = Total estimated time in min. per trip
D_H = Hauling distance in units of 100 linear feet
D_R = Return trip distance in units of 100 linear feet

This model corresponds to well-defined logging conditions, that is, flat to gently sloping ground, load not exceeding 1.2 cords, little snow, good hauling road, well-trained machine operator, and tractor in good operating condition.

Example of Use of the Model:

If $D_H = 1000$ feet and $D_R = 1200$ feet, the expected hauling time for a round trip will be:

$$T_E = 4.26 + 10(.46) + 12(.42) = 13.90 \text{ minutes}$$

This estimated time per trip is expected to vary between 9.07 min. and 18.73 min. (computed from the model variance). Outside these limits, the deviation is attributable to assignable causes such as machine breakdown, bad hauling road, operator lacking training, etc.

Once the model has been derived, it must be tested experimentally in the field. This is done by observing a certain number of trips and plotting them on a control chart. If data remain systematically inside the control limits, the model is said to represent adequately the work performed and may then be used for planning and control purposes. On the other hand, if data fall systematically outside the limits, the model is rejected and additional tests are taken to revise it.

Production Planning: Once the principle of a given logging system is well established, systematic production planning becomes possible. Planning devices, such as equations, inequations, graphs, nomographs, three-dimensional models, are prepared to suit planning needs. Special methods like allocation technique, replacement models, inventory models, and so forth, are also widely used for the purpose of optimizing managerial decisions. Here are two examples of planning devices derived from the mathematical model previously given.

In order to minimize logging fixed costs, a procedure by which the optimum length of the operations could be determined had to be found. After all factors involved in this problem were studied, a nomograph was developed to enable the foreman to determine the economic length of the operations without any computation, by simply drawing one line.

The nomograph is used by determining:

a) The number of machine-days necessary to perform the operation, and

b) The planning coefficient, which is the ratio of the cost to add one machine (ex: machine cost), to the daily overhead cost in the logging camp.

Example: $c_2 = \$3{,}000$
$c_1 = \$1{,}500$ per day
$y = 100$ machine-days

On the nomograph, for c_2/c_1 equal to 20 and y equal to 100 machine-days, the optimum length of the operations is 46 days. Thus, it would take two machines to perform this operation in an optimum manner, that is at a minimum cost.

Second Example: The two main hauling methods used at the Quebec North Shore Paper Company are tree-length logging and 4-foot wood operations. In order to determine which one of these two methods is more economical under certain given conditions, an analytical expression has been developed. Tree-length logging is more economical than 4-foot wood operations when

$$\frac{120\ t_1}{T_E\ t_2\ N} \geqq Pc - .04$$

where t_1 = number of trees taken on tractor
t_2 = number of trees per cord on proposed hauling area
T_E = mathematical model for tree-length logging $= 6.97 + .40\ D_H + .47\ D_R$
D_H = hauling distance in 100′
D_R = return trip distince in 100′
N = Total number of men required on tree-length logging, for one slasher unit.
P_c = Cutter's hourly production in cords, 4-foot wood.

example: suppose we have the following data:

$t_1 = 12$ trees per load
$t_2 = 17$ trees per cord
$D_H = D_R = 1700$ feet
$N = 12$ men/slasher unit
$P_c = .27$ cord per man-hour

then $T_E = 6.97 + .40\ (17) + .47\ (17) = 21.76$

$$\frac{120 \times 12}{21.76 \times 17 \times 12} \geq .27 - .04$$

$$.32 \geq .23$$

Conclusion: Tree-length logging should be used.

From the above analytical equation, the economic hauling distance, load per trip, and site type can easily be determined. The site type is definied by the value t_2.

This inequation will also be used for control purposes. Indeed, in logging, an operation that is statistically under control is not necessarily economical. Once statistical stability has been established, it remains to determine whether, under certain given work conditions, another method would not be more economical than the one actually used. This is done by computing an inequation like the one previously given.

Production Control: As presented above, the model is not very practical for control purposes since every hauling trip will have to be observed and plotted on a control chart. It means that one time-study man will be needed for every machine working on the operations. This system is expensive to operate. A way to go around this difficulty would be to control the average daily production instead of the individual trip. In doing so, the system would not be expensive to apply, but would be cumbersome and too complex for most of the foremen. Indeed, the system would require the handling of second-degree mathematical equations and the use of a series of control tables prepared in relation with the number of trips made, the load taken, and the hauling distance. To simplify the system, the variable to control (the round trip time) has been transformed.

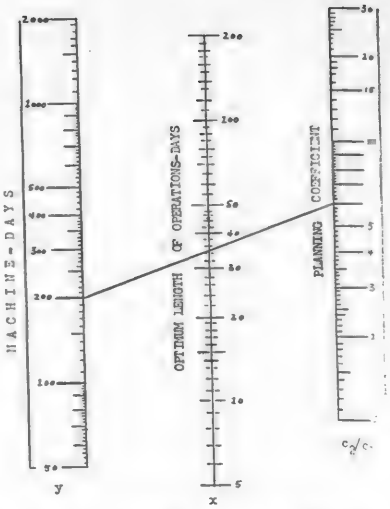


Fig. 1.—Optimum length of operation. *Example*: If $y = 200$, $c_2 = \$600$, and $c_1 = \$100$, then the optimum length of operations is 35 days. The number of machines required is $200/35 = 5.7$, or 6 machines.

If T_0 is designated as the observed (or actual) trip time and T_E as the estimated trip time obtained from the model, the variable to control is the quotient T_0/T_E. For most operations studied, the variance of T_0/T_E tends to be constant for any hauling distance and load taken per trip. Therefore, only one control chart will be necessary to control average daily production for any distance and average load. The expected average is, of course, equal to unity. This average is universal for any logging method. Control limits will be below and above unity and will vary with the sample size (see Table 1 and control chart).

Table 1.—CONTROL LIMITS FOR SELF-LOADING TRACTOR

Number of trips (Sample size) N	Average T_O/T_E	Control limits for the average $T_O/T_E = 1 \pm 3\sigma_{\bar{T}}$
1	1.0	0.60 and 1.40
2	1.0	.70 and 1.30
3	1.0	.74 and 1.26
4	1.0	.78 and 1.22
5	1.0	.80 and 1.20
10	1.0	.84 and 1.16
20	1.0	.88 and 1.12
30	1.0	.89 and 1.11
50	1.0	.90 and 1.10

Note: $T_E = 4.26 + .46\ D_H = .42\ D_R$ = Estimated time in min./trip.
T_O = Observed time in min./trip.

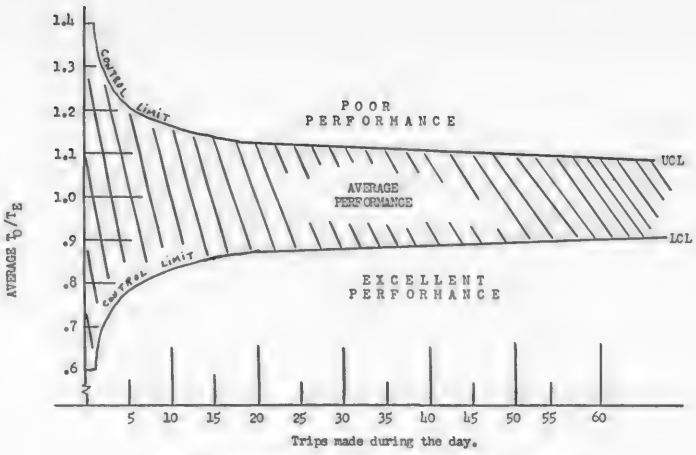


Fig. 2.—Control chart for self-loading muskeg.

Example of Use of Control Chart for T_O/T_E: To show the simplicity of application of the control limits table, two examples are taken:

Example 1: We have the following data:

$D_H = 1500$ feet
$D_R = 1400$ feet

Actual round trip time—$T_O = 24.56$ min. Is this observed time under control?

$$T_E = 4.26 + .46(15) + .42(14) = 17.04 \text{ min.}$$

$$T_O/T_E = \frac{24.56}{17.04} = 1.44$$

Upper control limits for N equal to 1 = 1.40 (see table or chart). Thus, the observed round trip time, 24.56 minutes, is out of control.

Example 2: The following data are obtained:

Operating time on Feb. 8th = 390 minutes
Number of trips made = 30
Number of cords hauled = 24.6
Average hauling distance = 645 feet

Is this production under control?

$$T_E = 4.26 + .46(6.45) + .42(6.45) = 9.94 \text{ min.}$$

$$T_O = \frac{\text{Operating time}}{\text{Number of trips}} = \frac{390 \text{ min.}}{30} = 13 \text{ min.}$$

$$T_O/T_E = \frac{13.00}{9.94} = 1.31$$

Upper control limit is 1.11 for N = 30 (see table). Thus, this production is out of control.

Practical Application of Control System: As it can be seen, the above system is extremely simple to use, and will give good results if information obtained is accurate. To get this information, the wood piles require a certain preparation before hauling starts. When scaling wood, the scalers are required to chain the hauling distance from piles to landing and to write it down on tags, which are attached to the piles. Later in the season, the haulers will pick up these tags as hauling proceeds and, at the end of each work day, will return them to the man in charge of production control. The amount of wood hauled, as well as the hauling distance, will then be known with enough accuracy, and production control, as explained in example II above, will be possible. To simplify preparatory work, however, some special control instruments are to be installed on all North Shore machines.

Main Difficulties Involved: Although very simple in its application, the system presented many difficulties during its preparation. The first one was met in setting up the sampling scheme. The problem was to define, as objectively as possible, the average worker. Finally, a satisfactory solution was found in statistical control principles.

The number of workers to observe, and the number of observations to take per worker, was also a problem. However, statistical theory has shown that, to minimize the total variance (within and between workers), one observation should be taken per worker and the number of workers to be observed should be equal to the sample size based upon the total variance.

Problems of assymetry of populations and heterogeneity of variance along regression curves were also frequent. Adequate solutions were found by transforming the variable. No definite laws for transformations can be given here, because the ones to use vary with each problem and are found on the basis of experience and judgment.

Results Obtained: The application of the above planning and control system derived from FOR techniques increased pulpwood hauling production with mechanical equipment by 40 percent on the average, and sometimes as much as 75 per cent. In addition, recommendations were made on optimum use of equipment, major faults to avoid, factors that limit the use of a given piece of equipment, number of machines to perform a given operation, and so forth.

From experience obtained to-date, FOR is a very promising science that will play a more and more important role in the economy of the forest industry in the near future.

Discussion

A. C. Barefoot (N. C. State College): Will the techniques for computing this variance be in the published paper?

Mr. Lussier: No, the techniques are explained in a company publication of about 200 pages and it would be impossible to cover them.

Mr. Barefoot: Is the company publication available?

Mr. Lussier: The publication belongs to the company for which I work, but I hope to publish it.

E. R. Hansen (Hamilton Mfg. Co.): Are there other companies using these techniques?

Mr. Lussier: Not that I know of.

N. Thomas Shelton (Diamond–Gardner Corp.): I think this technique may be useful in locating a sawmill site.

Mr. Lussier: I am sure it would be. In general, operators do not know which equipment would be most economical to use.

Mr. Winer: A great deal of work has been done by Korolef and others. There is a great gap between what has been published and what is practiced.

Mr. Lussier: The information that is available is not controlled by statistical methods. It is not known exactly where the data came from. Where two machines are compared they may have been working on different sites. Such data can not be statistically analyzed because they are incomplete. No conclusions can be drawn.

B. E. Mikulka (Southern Pine Lumber Co.): Is it correct that your method uses rather empirical formulas and compares the resulting "guesswork" with data collected by sampling in the field with the help of correlation? A similar method has been tried out for taking forest inventories in Europe.

Mr. Lussier: We don't know very much about this. In Europe there has been some work but in this country very little.

Boring Furniture and Cabinet Work

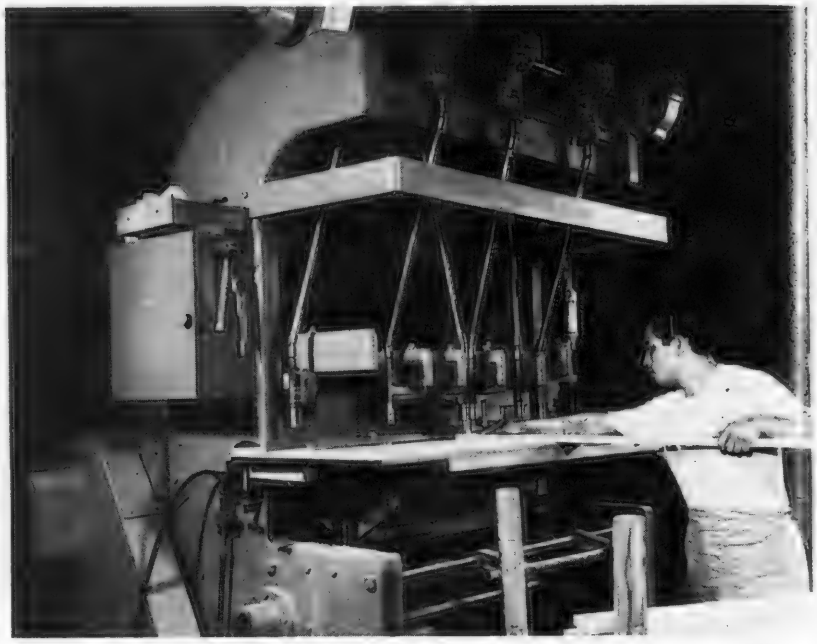
J. E. Hyler
J. E. Hyler and Associates, Peoria, Ill.

MANY DIFFERENT TYPES OF WOOD products are bored—different types of boring machines are used, and various kinds of wood boring tools are employed. Boring tools that are eminently suitable for one type of work are often unsuitable for another.

Some bits are especially designed for smooth boring in furniture and cabinet work. These are extension-lip tools, which have outlining spurs that sever wood fibers well ahead of the extension-lip cutting edges. They produce a particularly clean-cut hole, largely because the double-screw point provided gives a medium feed, for best results. These bits have a double twist pattern; chips are elevated through both channels. A diameter range from ¼ inch to 1 inch, by sixteenths, covers practically all demands in this particular field.

Bits like those described bore with less tearing of the wood than others. It is inevitable, however, that a small amount of tearing will take place as any boring bit emerges or "breaks through" the wood in boring "through" holes. If it is desired to avoid all possible tearing where boring bits emerge, one can use a spoil table of wood, and carefully set the machine so the outlining spurs barely score the surface. Where this is done, however, a "button" of wood is often cut loose, but remains unbroken. Therefore, it spins on the point of the bit, making it impossible to start the next cut without friction and burning.

If a bit is allowed to break all the way through, one is not troubled with such "buttons". In a few cases, where particularly exacting work imposes the necessity of contending with such buttons, operators brush them from the ends of bits with a soft pine stick. This takes time, however. In any case where material being processed has adequate thickness to allow for a subsequent light planing operation, it is well to do the boring on the break-through principle, while the material is still over-thickness, with the idea of taking a final cut from the parts at the planer. By this means, all tearing produced by boring bits as they emerge will be cleanly dressed away.



Operational view of the universal Greenlee gang borer, engaged on a two-hole, close-center job at California Furniture Shops, Los Angeles.

Some plants that have only a modicum of boring to perform find it best to use a single-spindle boring machine. High production in single-direction boring, however, particularly where two or more holes are being bored at a single pass, calls for use of a multiple-spindle borer.

One of the finest machines of this kind is a universal-spindle gang borer, so designed as to allow placement of the boring chucks in practically any desired pattern. This is possible because two universal joints, plus a telescopic spindle section between those joints, is incorporated in each spindle. In this way, length compensations are automatically made in the spindles, and boring chucks may be placed wherever desired. Their axes remain vertical.

Special bit clusters can be furnished in any case where extra-close center hole groupings are required, and also to make for fast setup in cases where the same pattern of hole spacing is frequently employed. However, standard spindles can be set as close as 1½ inches apart, and it is possible (in a specific case) to obtain spindles for 1¼, 1⅛ or 1 inch minimum centers if desired.

Such machines are used in length from 4 feet to 22 feet, depending on largest workpieces to be handled. The rule is to install a machine big enough to take care of largest workpieces, but no bigger than this. For any specific job, any number of spindles may be left idle, as need or expediency may dictate.

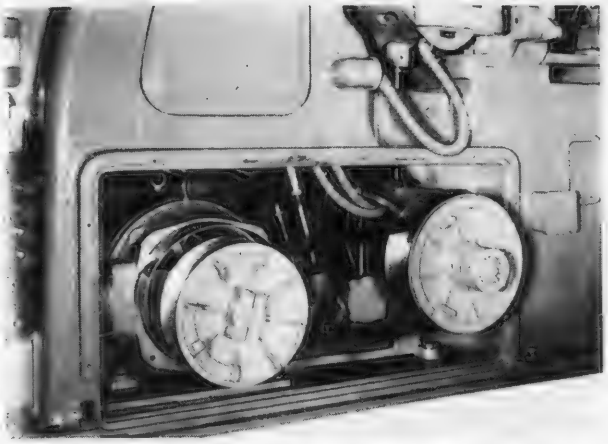


Fig. 1.—Variable-speed motor drive unit, a recent development in rip-saw design.

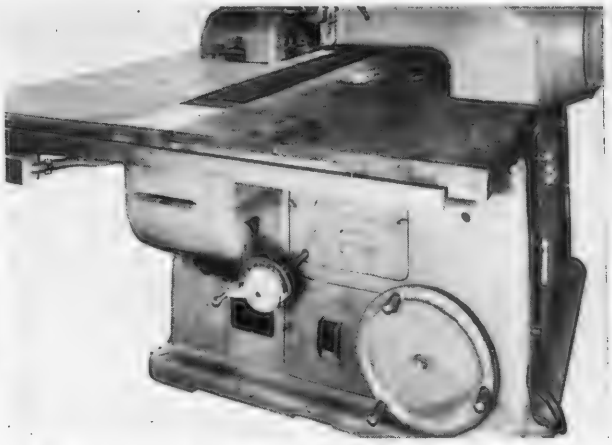


Fig. 2.—Vari-drive units such as this make it possible to obtain any speed feed in constant increments.

NEW TECHNIQUES, DEVELOPMENTS IN

Rip Saws and Moulders[1]

G. A. Johnson
Mattison Machine Works,
Rockford, Illinois

Variable speed drive units on rip saws give the operators greater control over quality. Actual design improvements such as this plus attachments that replace mechanical handling or eliminate guesswork are the principal subjects discussed.

Fig. 3.—Semi-automatic panel lay-up gauge. There are a variety of different types; this one can be used on either side of the saw blade.

From the forest to the finished wood product, the saw in its various forms is an indispensible woodworking tool. That statement should make it quite obvious that the first subject here will be straight-line, power-feed rip saws. The subject will be confined to some recent developments in power-feed, straight-line rippers, including some noteworthy accessories. These accessories were created to perform specific functions in conjunction with the common art of ripping, as it applies to the woodworking industry.

This would be an opportune place to pay tribute to the manufacturers of saw blades. The constant improvement of their product has been a vital, contributing factor in the development of better machines.

One of the recent developments in rip-saw design has been the incorporation of variable-speed drive units. Figs. 1 and 2 illustrate motor vari-drive units. This type of drive provides the means for obtaining any feed speed in constant increments, from the minimum to the maximum within the range of this unit. This feature enables the operator to select quickly the feed rate best suited to the material being processed. This means better control in securing the quality of work desired on any material. There are also hydraulically driven feed units being used that provide the same operating conditions described for the motor belt type units. This hydraulic unit involves the addition of oil tank, pump and fluid motor as well as piping.

Fig. 3 illustrates a panel lay-up gauge. This unit would be classified in the category of accessories. There have been a number of different types of lay-up gauges built, and to cover them all would require an excessive amount of space. The arrangement shown is a semi-automatic type, and embodies all the features of a modern unit. This gauge can be arranged for use on either side of the saw blade, and is therefore

[1] Presented at Session II, Wood Machining, FPRS 12th National Meeting, June 22–27, 1958, Madison, Wis.

The Author: Gustaf Johnson is Chief Draftsman at Mattison. He has been in their engineering department 37 years, both designing woodworking equipment and working directly with customers and their requirements.

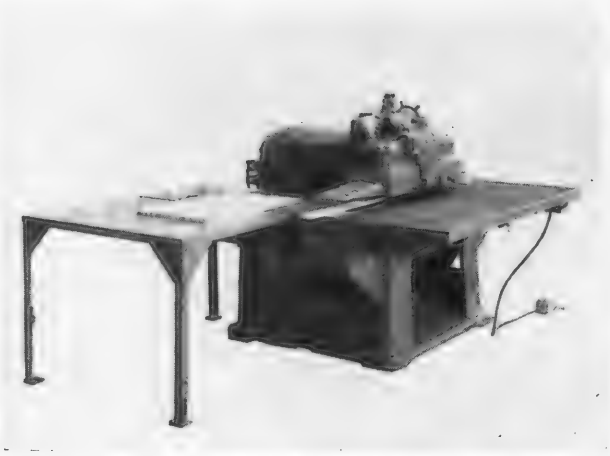


Fig. 4.—A lay-up table should be used in conjunction with a lay-up gauge. The table should have an adjustable stock stop for setting panel width.

Fig. 5.—A pre-select, semi-automatic hydraulic rip gauge. Ri width can be varied in ⅛-inch increments; this gauge has 98 inc vidual settings.

adaptable to almost any plant condition. It is also possible to use two units of this design on a machine, one on each side of the saw blade. This is done principally for color-matching panels.

Laying up panels has been an awkward, time-consuming operation of passing stock back and forth across the saw table. This was necessary to get the proper width on the final rip. This type lay-up gauge eliminates all unnecessary movements, thereby increasing production very substantially. A brief description of this gauge would be as follows. It is composed of a slideable stock gauging bar at the rear of the machine, and an automatically adjusted rip gauge stop at the front of the machine.

The movement of these parts is accomplished by an electrically controlled, solenoid-operated valve, and an air cylinder. The control is by a portable foot switch that can be placed at the infeed or outfeed end of the machine, as desired. The stock gauging bar and the rip gauge stop are mechanically connected, and move simultaneously. When the foot switch is depressed, the stock gauging bar instantly moves against the partially laid-up panel. As the gauging bar and the rip gauge stop move together, the rip gauge stop will be set in the proper position to rip the exact width board required to complete the panel. When the foot switch is released, the stock gauging bar and the rip gauge stop return to a neutral position. A lay-up table (which in most cases is optional) should be provided (Fig. 4). The table should have an adjustable stock stop that can be set for the desired panel width. A scale can be provided in the table for convenience in setting the stock stop.

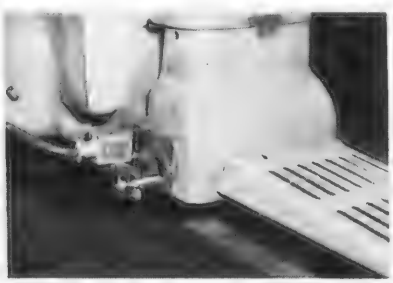
Fig. 5 illustrates another recent development that can be classed as an accessory. This unit is known as a pre-select semi-automatic hydraulic rip gauge. The complete unit consists of an oil tank or reservoir, a hydraulic pump with direct-connected motor, a group of hydraulic cylinders of various sizes, solenoid-operated hydraulic valves, electrical relays mounted in a dust-tight cabinet, a portable push-button station, and necessary guards and covers. The hydraulic cylinders are actually two groups, one group of inch-increment cylinders of various lengths and one group of fractional-inch-increment cylinders.

The inch-increment cylinders are arranged into two tandem sets. These sets are mounted side by side in a parallel position. The piston rods from these sets project in opposite direction One rod is attached to the slideable ri gauge; the other rod is attached t a toggle link arrangement to whic the group of three fractional-inc increment cylinders are connected. Thi cylinder and toggle link arrangemer t is the means devised for moving th rip gauge in ⅛-inch increments or an multiple thereof, up to the full ca pacity of 14 inches.

One cylinder in each of the inch increments sets is a differential type, or double-acting cylinder. This is accomplished by having the net area of the piston under line pressure at all times, which causes the piston to retract as soon as pressure is released on the opposite side of the piston. This results in all of the conventional or single-action cylinders being retracted by the differential lead cylinder. The three fractional-inch-increment cylinders are also the differential type.

The action of the hydraulic cylinders is controlled by push buttons mounted in a portable floor-stand pedestal. The console of the floor stand is equipped with sufficient push buttons to enable the operator to select any rip width in ⅛-inch increments within the rated capacity of the unit. The push buttons on this console are the large, mush-room type, conveniently spaced for easy selection. This particular gauge unit has 98 individual settings.

Incorporated in the electrical circuit of this unit are two safety interlock switches, one mounted on the infeed roll housing, the other at the outfeed end (Fig. 6). These switches are actuated by the stock passing through the machine. As soon as a board enters into the machine, the operator can press any button on the console to change the gauge setting for the next rip width. The safety switches form a holding circuit that will maintain the gauge



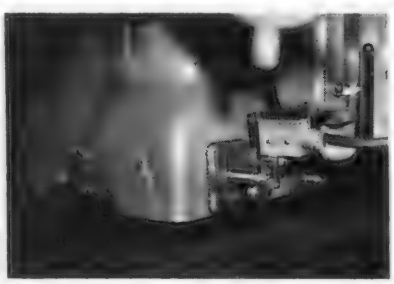


Fig. 6.—Safety interlock switches are incorporated in the electrical circuit of the pre-select gauge, one at the infeed roll housing, the other at the outfeed end. These switches form a holding circuit to maintain the gauge setting while a board is being cut.

ig. 7.—A two-blade straight edger for double edging rough lumber.

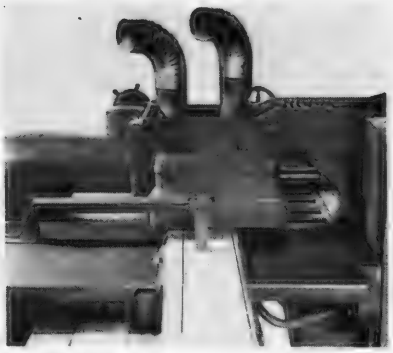


Fig. 8.—The right-hand saw blade is fixed, while the left is on a slideable spindle.

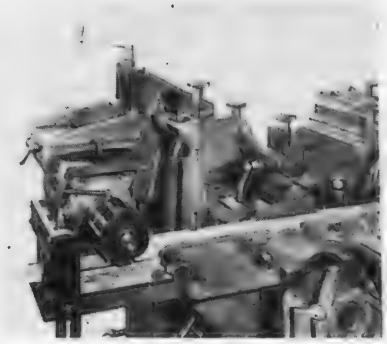


Fig. 9.—This auxiliary motor mounting might be considered a fifth cutterhead. It can be furnished in 5, 7.5, 10, or 15 horsepower.

setting until the board in the cut passes the switch on the outfeed roll housing.

If a new gauge setting has been selected, the next board must not enter the machine until the gauge has shifted to the new position. This requires a very short time, depending on the feed rate being used. A gauge of this type when properly handled is without question a valuable accessory for saving time and material.

Another new machine was developed recently for double-edging rough lumber (Figs. 7 and 8). For identification it may be called a two-blade straight edger. The saw blade on the right is a fixed-position unit. The left-hand saw blade is mounted on a slideable spindle unit. The movement of the slideable saw unit is accomplished by hydraulic cylinders, electrical relays, solenoid-operated valves, and is controlled from a remote-control push-button station. The hydraulic and electrical systems that operate the slideable saw-blade unit on this machine have the same functional principles as those described for the pre-select rip gauge.

The right-hand, fixed-position saw unit has the motor mounted directly on the saw spindle. The slideable saw spindle unit is driven by V-belts. The saw spindle is splined and fits into a splined sleeve arrangement on which is mounted the V-belt sheave. The driving motor is adjustably mounted in the base of the machine. A very substantial slideable frame provides a rigid spindle mounting that will maintain perfect alignment of the saw blade. The mass weight to be moved has been reduced to a minimum for smooth and quickly responsive movement.

Basically and primarily, this machine was designed to double straight-line rip lumber into pre-selected width boards. There are also other potential uses, such as straight edging one edge, ripping any stipulated width board between the saw blades, and many other variations. The fixed-position saw kerf can be indicated by the use of a guide-line light.

There are still a number of rip-saw developments that deserve mentioning. One is the recently introduced double ripper, which has two single-blade saw units built as one machine. The feed units run in opposite directions, or can be run in tandem. There are also several improved designs of gang rippers, which have greater production capacity and produce a higher quality work.

Molder Improvements Have Been in Capacity and Versatility

The fundamental purpose of a moulder is to dress lumber into specific sizes of plain and formed pieces of stock for various uses. There have been practically no changes in the fundamentals of processing stock in a moulder. There have, however, been a number of innovations offered in the number and location of cutting heads. These designs have added to the production capacity and the versatility of the machine in processing many types of formed stock. In addition to this advanced engineering, know-how in the use of recently developed material has been responsible for the tremendously advanced end product now available. One example is the extensive use of alloy steels, heat treated for greater stability and infinitely improved wearing qualities. Cast irons produced from scientifically prepared formulas, which control the metal mixture and process of melting, have created a uniform structure of greater strength. These technical advances have made possible a very marked improvement in the fundamental design and built-in quality of the machine.

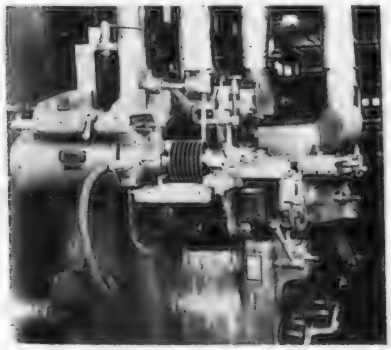


Fig. 10.—Here the fifth head is arranged or gang ripping crib stock. Top and bottom eads have moulded the formed edges.

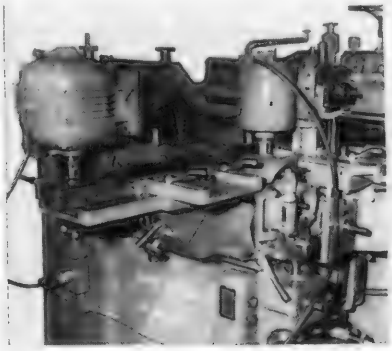


Fig. 11.—These two smaller units are used for small, supplementary rabbets or grooves that are not easily cut with side heads.

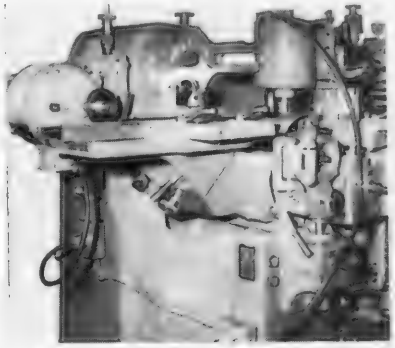


Fig. 12.—These smaller units may eliminate the need for more expensive cutterheads, and may perform operations regular heads cannot do.

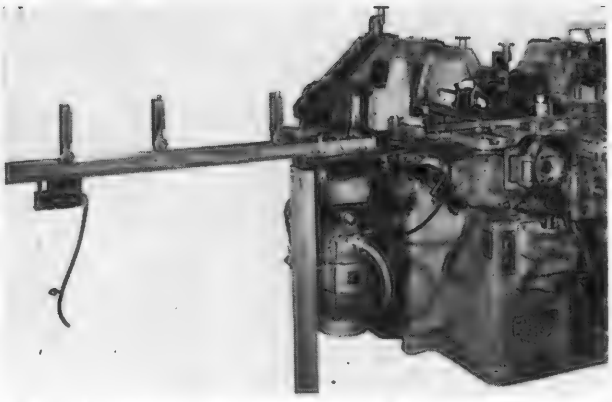


Fig. 13.—Jump-cut attachment developed for sash and door mills, with horizontal- and vertical-spindle jump units, screen moulds, stock trough, and control switches.

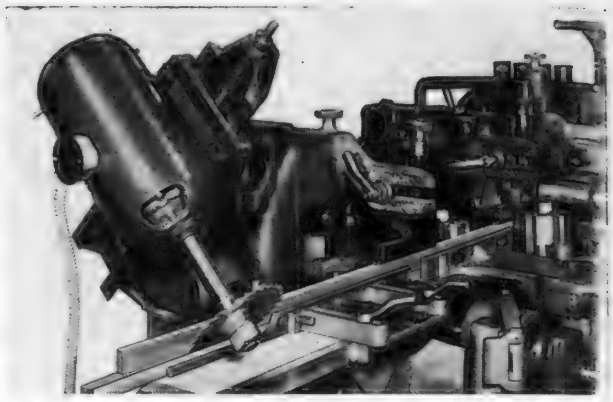


Fig. 14.—This unit is splitting a glue block, but it can perform a variety of jobs. It can cut horizontally or at various angles, and has both vertical and horizontal adjustments.

There have also been improvements in design to increase production capabilities, simplify set-up procedure, and improve safety in operation. These developments include improved initial drive designs by application of variable-speed units, both mechanical and hydraulic. Stock feeding mediums have been improved to provide substantially increased feeding rates, and additional feed rolls have been incorporated for increased traction and smoother action. Top-feed rolls have been replaced with lag-type feeding chains for certain kinds of work. Changes are also evident in the methods of mounting cutterhead spindles, as well as the design of spindles, and in the use of various components and methods for opening the machine quickly when changing set-ups or clearing a jam-up. These and numerous other developments, which are considered of a minor nature, have all contributed to the ultimate production of a woodworking machine of excellent quality.

To augment the improvements of the conventional machine, a number of attachments have been developed to add to its versatility and productive capacity. The following figures are typical and are used only as a means of illustrating what has been accomplished.

Fig. 9 illustrates an auxiliary motor mounting that can be considered a fifth cutterhead, with reservations. Fig. 10 shows it arranged for gang ripping crib stock run in multiples. The top and bottom heads have moulded the formed edges of the slats. This unit is large enough to handle a number of jobs. Motor units of this type can be furnished in 5, 7½, 10, or 15 horsepower.

Fig. 11 illustrates two smaller motor units that are used for small supplementary rabbets or grooves, which are not easily cut with the side heads. In many instances, these units will eliminate the need for expensive cutterhead equipment. They will also perform a number of operations that cannot be done by the regular heads on the machine. Fig. 12 shows the same units with the motor at the outfeed table in a horizontal position.

Fig. 13 is a close-up of what is known as a jump-cut attachment. This was developed for use in sash and door mills. A number of plows, rabbets, and grooves of various lengths must be cut at specific points on the stiles and rails. The stiles and rails are completely formed, and the screen mould is also formed and separated from the stile or rail in one operation. A chute is provided to lead the screen mould up and out to the rear. Mounted on the end of the machine is a horizontal motor unit. This motor drives a separately mounted spindle unit arranged for up and down movement. The movement of the spindle is accomplished by a solenoid that is actuated by a switch, which is tripped by the stock as it passes through the machine. Thus, the cutter on the spindle is made to jump in and out of the work at specific points.

The vertical jump unit is of the same type and design. In this instance, the vertical unit is being used to jump cut the rabbet for the door panel. The trough extending to the rear guides the stock and supports the switches for actuating the jump units.

For lack of a better name, the unit in Fig. 14 may be called a glue block splitter, since that is the operation being performed. It is quite apparent that the unit can be used for a variety of jobs. It can be tilted for various angle cuts as well as for cutting in a horizontal position. It has both vertical and horizontal adjustment.

From the foregoing, it is quite obvious the modern moulder can be equipped to perform a number of specialized jobs on a production basis.

In closing this subject it may be stated that there is much more that could be said in regard to very recent developments, and also regarding that which will be available in the near future.

Another new machine available to the woodworking industry is a wide abrasive belt sizer, sander, polisher. Because of the massive and rigid construction, this machine will remove stock equivalent to planer cuts and will produce a sanded finish. It will maintain very close tolerances over large surfaces. Arrangements are available to set up for very high-grade finish sanding and polishing. The abrasive-belt drive can be arranged for motors up to 150 horsepower, or sufficient power to perform any job the abrasive belt is capable of doing. The feed drive has a variable speed arrangement with a 3:1 ratio. These start at 20 fpm. The top speed ratio currently available is from 100 to 300 fpm feed. Feed motors up to and including 15 horsepower are presently available. A machine of this type should be well received by the sanding departments of plywood, hardboard, particle board and other plants producing large surface material that must have a smooth surface finish and be held to close tolerances.

Another item that has not been included in this discussion, and which may be of interest to many is a new wood turning lathe. This is a full automatic machine. It is equipped with means of adjustment for any cycle of operation best suited to the stock being turned and the production required. Controlled air power furnishes the motivation for the automatic cycling.

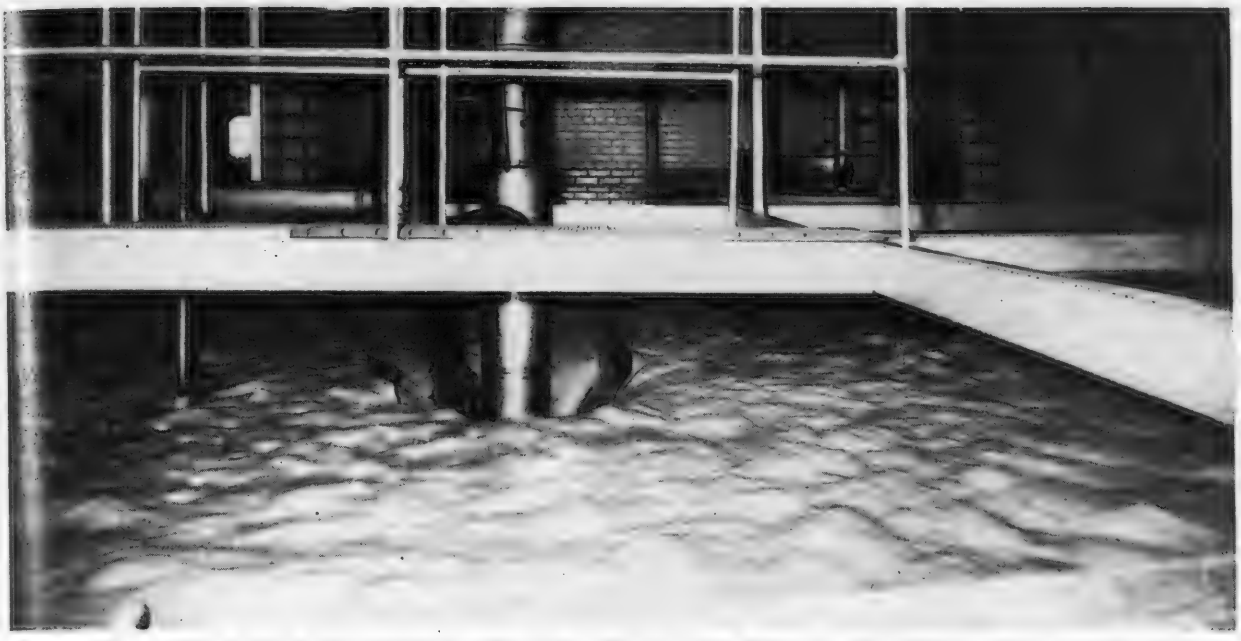


Fig. 1.—View at top of the fermentor in which yeast cells are grown. Shown are the emulsion surface, air-supply feed pipe, and the open end of the fermentor draft tube.

The Production of Nutritional Yeast from Spent Sulfite Liquor[1]

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Production of edible protein from spent sulfite liquor was developed in Germany. Studied here by Sulphite Pulp Mfr's Research League. To be competitive, costs must come down or markets open up.

UTILIZATION OF THE NON-FIBROUS one-half of the dry pulp log, which is traditionally and usually of necessity wasted, has long been the goal of the sulfite pulp industry. Since the process was first commercialized some 80-odd years ago, there have been literally hundreds of schemes worked out for spent sulfite liquor utilization, and hundreds of products have been prepared from this intriguing material. Many of the schemes proposed have been technically quite sound, and many of the products prepared have had real merit. The difficulty has always been, with relatively few exceptions, that the products either weren't quite good enough or were too expensive to meet competition from similar products produced from less refractory starting materials.

One of the products derived from sulfite liquor that shows some promise of eventually being competitive and that has recently been put into commercial production is nutritional yeast.

The idea of growing microorganisms on the simple sugars present in spent pulping liquor is not new. Ethyl alcohol has been produced through the culture of *Saccharomyces* yeasts in this substrate for a great many years, particularly in Europe (1).[2] Similarly, other organic products of microbiologic metabolism have been prepared from wood sugars, although almost without exception such preparations have never progressed beyond the laboratory stage (2–9).

Probably the Germans first thought of converting wood sugars into edible protein rather than into alcohols and the like (10, 11). The idea was seemingly born during World War I days when it became necessary to seek out new protein sources to circumvent the Allied blockade. The process was first put into large-scale commercial production during World War II. Common yeast *(Saccharomyces)* might have been used for the process, but wood sugar is a mixture of both five- and six-carbon molecules, and this yeast can assimilate only the six-carbon variety. A number of different yeast species were actually used in Germany, but one of them, then classed as *Torulopsis utilis* and since reclassified as *Candida utilis,* appeared to find the most favor.

The Sulphite Pulp Manufacturers' Research League in this country started growing yeasts on spent liquor in 1943

[1] Presented at Session XIII, Chemical Utilization, FPRS 12th National Meeting, June 22–27, 1958, Madison, Wis.

[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

The Authors: Jess Holderby, General Manager of Lake States, holds a BS in chem. eng., MS in sanitation. He previously was research coordinator for the League.
W. A. Moggio is Production Manager at Lake States.

(12). After screening many organisms for growth characteristics and dried cell composition, they too chose to concentrate on *T. utilis*. When the war was over, they obtained detailed information on the German developments, fitted it in with their own pilot experience, and proceeded to lay out a commercial continuous flow process. Presently there are two sulfite pulp mills in the United States that make "Torula" yeast, and both are using what may be termed the "League" process.

Spent Sulfite Liquor

The sugar source for the manufacture of Torula is the liquor that results from the treatment of wood chips, under conditions of elevated temperature and pressure, with an aqueous sulfurous acid solution of calcium bisulfite (13, 14). During the digestion period, lignin combines with the sulfur dioxide or sulfite ion to form calcium lignosulfonate. After the cooking process is completed, the acid liquor containing the dissolved materials is separated from the insoluble cellulose. Other bases such as sodium, ammonium, or magnesium can be used in place of the calcium to form the cooking acid.

Somewhat over one ton of dissolved wood solids is produced with each ton of pulp made. The organic matter present in the liquor is complex, with only about 20 per cent of the dissolved solids being made up of easily oxidized sugars and related products. Thus, some 400 pounds of fermentable material are produced for each ton of pulp made, or 20 tons total for a mill that produces 100 tons of pulp per day. Of this quantity, only 14 to 16 tons are usually collectible at a practical concentration.

The concentration of the spent liquor from different mills ranges widely, from 60 to 150 grams of solids per liter (500 to 1,250 pounds per 1,000 gallons). The variation results from the type of wood used and the degree of cooking required to produce the desired pulp quality. Liquors from the pulping of hardwoods have a higher proportion of sugars (up to 30 per cent, solids basis) than do softwood liquors (15 to 22 per cent, solids basis). The types of sugars are also a function of the wood used. Softwoods yield a product with a total sugar of about 75 per cent hexose, largely mannose. Liquors from hardwoods may have as much as 70 per cent pentose sugars, mostly in the form of xylose. Hardwood liquors may also have a higher content of acetic acid. Table 1 (12) shows the approximate composition of spent sulfite liquors from spruce wood.

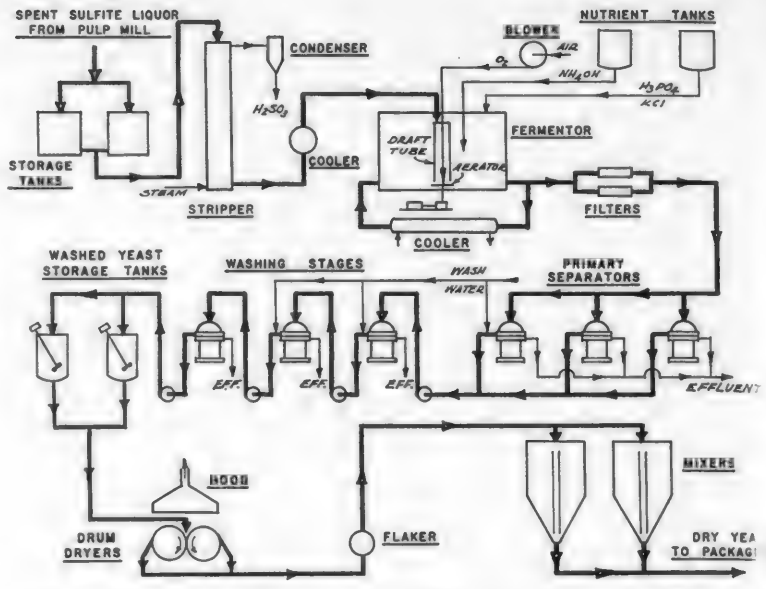

Fig. 2.—Flow sheet for the production of nutritional yeast from spent sulfite liquor.

Yeast Production

Fig. 2 is a flowsheet for a commercial Torula plant. The over-all process can be subdivided into steps as follows: (a) liquor collection and preparation, (b) yeast propagation, (c) yeast recovery, and (d) yeast drying.

It is usually axiomatic in any processing operation that the material to be processed should be in as concentrated a form as possible, primarily as an economic consideration. In the case of spent sulfite liquor, the efficiency of the liquor collection system is of great significance. Collection-system efficiencies probably vary from less than 50 per cent to a maximum of about 90 per cent, based on the total solids produced by the pulping operation. The efficiency will vary, depending on the equipment used for draining and displacing the spent liquor from the pulp.

Liquor preparation involves reducing the sulfur dioxide content of the process feed to a point where it will not inhibit yeast growth. Sulfur is present in the raw liquor in a number of forms. For convenience, these may be termed (1) "inorganic", or that which will reduce iodine in a cold acid solution; (2) "organic loosely combined," which reduces iodine in acid solution only after being first split from its organic complex by strong alkali treatment; and finally (3) "firmly combined sulfur", which does not reduce iodine even after alkali treatment. This firmly combined sulfur does not interfere with yeast growth while the other two forms do.

Effective liquor preparation can be accomplished by lime treatment, which in general results in the precipitation of calcium sulfite; or by conventional stripping in a tower with steam or other gas.

Factors of prime importance in the propagation step include holding time, rate at which fermentables are added, air supply, nutrient supply, temperature, and pH.

In common with other continuous processes that involve a time reaction, it is essential to provide sufficient residence time in the reactor (in this case the fermentor) to permit the desired reaction to attain virtual completion. The time it takes for a single yeast cell to bud and split into two mother cells depends upon nutritional and environmental conditions, and will vary widely. Experience in growing Torula by means of the League process indicates a practical minimum holding time of approximately three and one-half hours.

The rate of addition of the fermentables must be adjusted to parallel closely the rate of usage by the yeast culture. It appears that yeast growth is most vigorous when the concentration of fermentables in the wort is held at a minimum. In effect, it appears desirable to approach the point of cell starvation, but not to permit actual shortages to occur. Loadings of fermentables (expressed as dextrose) of 160 pounds per hour per thousand

Table 1.—COMPOSITION OF SPENT SULFITE LIQUORS FROM SPRUCE WOOD

	Grams per liter*
Neutralized solids	100
Total sugar (as glucose)	75–22
Hexose	11–16
Pentose	4–6
Volatile acids (as acetic)	2–5
Sulfur (all forms as SO_2)	3–10
Total inorganic (free SO_2)	0.5–2.
Organic (Loosely combined SO_2)	3.0–5.
Lignin (as lignosulfonate)	0–65
Calcium	7–10
Miscellaneous compounds	2–5
pH	1.5–3.

*Variations based on liquors of the same solids concentration.

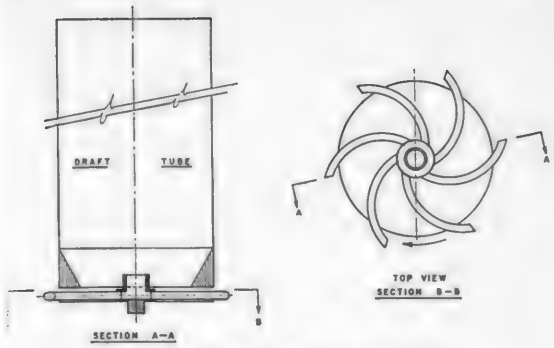

Fig. 3. —The Waldhof aerator wheel.

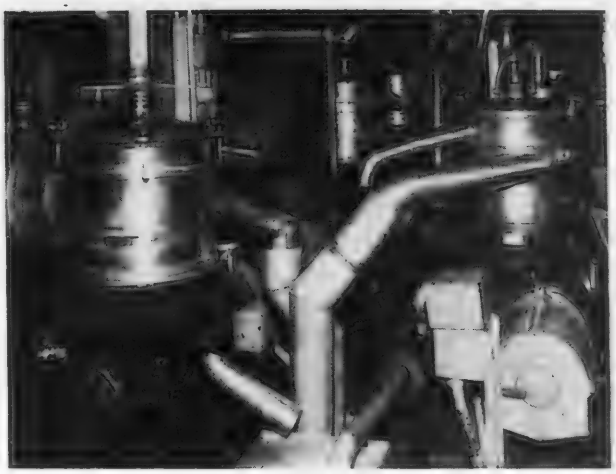

Fig. 4.—Nozzle-type continuous centrifuges used for yeast-cell separation and washing stages.

cubic feet of fermentor space are common, although somewhat higher loadings have been successfully handled experimentally.

The growing of Torula yeast, being an aerobic process, requires oxygen, which is normally furnished as air. The quantity of air supplied to the fermentor and the manner of its distribution are critical factors in yeast growth and the assimilation of the liquor sugars. Because of the foaming characteristics of the spent sulfite liquor, a mechanical aeration system—the so-called "Waldhof" unit shown in Fig. 3—which incorporates a foam-control feature is ordinarily employed (15–17). High efficiencies of oxygen transfer at the air-liquor-yeast interface are obtained through the formation of emulsions that have as much as two volumes of air for each volume of liquor.

The amount of air required for efficient growth of yeast is critical. Too much air can be accompanied by increased carbon dioxide respiration, increased heat formation, and lowered yeast yield. Too little air results in anaerobic fermentation conditions, which favor alcohol production and again cause a decrease in yeast yields. Air requirements are difficult to specify because the efficiency of aeration (oxygen transfer) varies with different substrates, and with types and sizes of equipment used for aeration. Satisfactory aeration with spent sulfite liquor substrates has been reported as low as 150 Cfm of air per pound of dry yeast produced.

Inorganic Requirements for Yeast Growth

For efficient growth, yeast requires nitrogen, phosphorus, and potassium in relatively large amounts, and calcium, magnesium, copper, iron and certain other elements in smaller amounts (10, 11). Spent sulfite liquor is almost totally lacking in nitrogen, phosphorus, and potassium, and in some instances magnesium. These inorganic elements are furnished usually in the form of ammonium hydroxide, phosphoric acid or one of its salts, potassium chloride, and magnesium carbonate.

The growth of yeast under aerobic conditions results in the liberation of large amounts of heat, which necessitates the use of cooling water or refrigeration. The quantity of heat released per pound of yeast will differ with different substrates. When fermented, pentose sugars release larger quantities of heat than do the hexose sugars. In the case of spruce spent sulfite liquor, approximately 1,700 Calories of heat are evolved per pound of dry yeast produced (12). Efficient yeast growth on a continuous basis requires the maintenance of an even temperature in the fermentor. For normal growth of Torula Yeast, the temperature should be maintained in the range of 93 to 98°F (10, 11). Increased temperatures result in reduced efficiencies, and several days may be required for the yeast to recover from heat shocks.

Torula yeast will grow satisfactorily in the pH range of 4.5 to 6.0 (11). Control of the substrate pH, however, is important for a number of reasons. Where higher temperature operation is required and where sugars are fed in high concentrations, the lower pH levels are used. This is done to prevent bacterial contamination, which is more likely to occur at high pH and temperature levels, particularly when the holding time in the fermentor is long because of the high sugar concentration feed. Control of pH is conveniently accomplished by the controlled addition of an excess of ammonium hydroxide, although other common basic compounds may be used.

Recovery of the cell material produced in the fermentor is strictly a matter of physical separation (10, 11). Filtration by means of conventional vacuum filters has been used to some extent, but has usually been of dubious merit because of the tendency of the yeast to "blind" the filter cloths. Solid-bowl centrifuges have been used successfully, but have the disadvantage of discontinuous operation and high labor requirement. Most Torula yeast produced today is recovered in nozzle-type continuous centrifuges, which are operated in series with dilution between stages to accomplish the desired degree of washing.

Drying is an essential step in the production of nutritional yeast. The cells must be inactivated, so they are heat killed. To permit economical handling between plant and consumer and to prevent bacterial spoilage, the cell material must be dried to a powder. Spray drying has been used to some extent in Germany for this step, but in this country drum drying is practiced exclusively (10, 11).

Depending upon the total content of fermentables in any given liquor, a yield of dry yeast substance approaching 50 per cent by weight of the reducing sugars fed can be expected. A typical analysis of Torula produced from sulfite liquor is given in Table 2.

Economic Status of the Process

The production of nutritional yeast from spent sulfite liquor is surprisingly expensive, when the market value of the chief raw material is considered. The liquor itself is extremely corrosive, and stainless steel or its equivalent must be extensively employed for piping and equipment. Construction costs

Table 2.—TYPICAL ANALYSIS OF DRIED TORULA YEAST

	%
Moisture	6.5
Crude protein (N x 6.25)	52.0
Crude fat (with prehydrolysis)	4.5
Minerals (ash)	7.8
Carbohydrates (by difference)	29.2

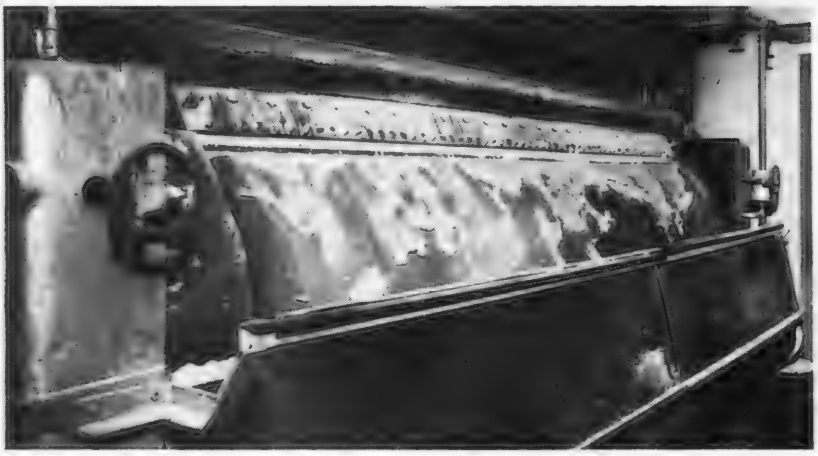

Fig. 5—Steam-heated drum dryer. Dried yeast is being removed by the knife blade at the top of the revolving drum.

for a plant such as has been here described and sufficient in size to serve a 100-ton pulp mill have been estimated at approximately $1,500,000. Such a plant could be expected to produce approximately 2,500 tons of yeast per year. Operating expense, in terms of labor, maintenance, nutrients, steam and power, will more than equal capital expense by a substantial margin.

The obvious markets far nutritional yeast are as a protein concentrate (11). Its usefulness as a supplement, especially to predominantly cereal diets, for both domestic animals and humans has been well demonstrated here and abroad. Market acceptance, however, has lagged considerably behind in many areas.

In the animal field, the major deterrent to wider usage is price. Here yeast's basic competition is soymeal. At prices that would permit yeast protein to compete dollar for dollar with soy protein, there is little doubt as to the ability of the feed market to absorb substantially all the dried yeast that could be produced from all the wood sugar presently in sight. Unfortunately, such a price would have to be, judging from current soymeal quotations, probably not over 4¢ per pound.

Dried yeast does furnish factors other than protein, however, that are valuable in certain feeds and that are either lacking or are present in adequate amounts only in the conventional basic feed ingredients. As a result, a market price of from 8¢ to 10¢ per pound has been maintained for the limited yeast supply currently available. It is doubtful if yeast can be produced from wood sugars at a cost that would make the operation attractive at the above market levels, and it is a foregone conclusion that any substantial increase in the available supply would make the economics even less attractive.

Dried yeast has been used in various factory-processed human foods for at least 20 years. Until recently, the only yeast available for this use has been the common or *Saccharomyces* type, grown usually on molasses or grain substrates. Various factors, including price, taste, odor, and so forth, have operated to limit the use of yeast for this application to a rather small fraction of what its apparent potential would be under more favorable circumstances.

When Torula first became available, its acceptance in the human field was almost completely blocked by an understandable reluctance on the part of the food manufacturers to change from a time-proven product to one they had no experience with. To assist in overcoming this reluctance, a petition was submitted to the United States Pharmacopeial Convention requesting publication of specification for Dried Torula Yeast. There immediately arose a flood of objections, substantially all of which were apparently inspired by competition. The basic fitness of Torula for human consumption, and the suitability of wood sugars as a raw material for its growth were questioned. Even the wisdom of permitting such "unskilled and inexperienced operators as are common in the wood processing industry" to engage in the production of human food was brought into the debate.

The U.S.P. specifications was eventually approved, published, and made official as of September 1, 1956 (18). While this action on the part of a highly respected scientific body had a very salutary effect on the technical segment of the food industry, it did not solve the marketing problem. Echoes of the controversy are still contributing heavily to sales resistance. Advertising and marketing people in the food industry are still wondering what effect these echoes will have on their own sales of products that contain Torula. Obviously, progress in this field will be slow.

Earlier yeast was referred to as one product derivable from spent sulfite liquor that shows some promise of eventually becoming competitive. The fulfillment of that promise, if and when it comes, will result from either a substantial reduction of present process costs or a decided improvement in its market prospects. Either one is a possibility!

Literature Cited

1. McCarthy, J. L. 1954. Alcoholic fermentation of sulfite waste liquor; Industrial Fermentations; Vol. I, Ch. 4; Underkofler & Hickey, Editors; Chemical Publishing Co., N. Y.
2. Anon. 1940. Sulfite waste liquors—an annotated bibliography, Inst. of Paper Chemistry, Appleton, Wis.
3. Anon. 1947. Sulfite waste liquors—an annotated bibliography, first composite supplement, 1941–46. Inst. of Paper Chemistry, Appleton, Wis.
4. Anon. 1952. Sulfite waste liquors—an annotated bibliography, second composite supplement, 1947–51. Inst. of Paper Chemistry, Appleton, Wis.
5. Marshall, H. B., and M. A. Johnson. 1952. Utilization of sulphite waste liquor: TAPPI 35 (1): 146A.
6. Marshall, H. B., and J. M. Neale. 1954. The utilization of sulphite waste liquor. TAPPI 37 (1): 156A.
7. Marshall, H. B., and J. M. Neals. 1954. The utilization of sulphite waste liquor. TAPPI 37 (8): 174A.
8. Marshall, H. B., and A. I. MacDonald. 1955. The utilization of spent sulphite liquor. TAPPI 38 (7): 165A.
9. Marshall, H. B., and A. I. Cunningham. 1956. The utilization of spent sulphite liquor. TAPPI; 39 (7): 171A.
10. Wiley, A. J. 1954. Food and feed yeast. Industrial Fermentations; Vol. I, Chap. 10; Underkofler & Hickey, Editors; Chemical Publishing Co., N. J.
11. Dunn, C. G. 1952. Food yeast. Wallerstein Laboratories Communications; 15, 48, 61, 79.
12. Inskeep, G. C., A. J. Wiley, J. M. Holderby, and L. P. Hughes. 1951. Food yeast from sulphite liquor. Indus. & Eng. Chem. 43 (8); 1702.
13. Hagglund, E. 1951. Chemistry of wood; Academic Press, N. Y.
14. Sutermeister, E. 1941. Chemistry of pulp and paper making; John Wiley & Sons, N. Y.
15. Saeman, J. F., E. G. Locke, and C. K. Dickerman. 1945. The production of wood sugar in Germany and its conversion to yeast and alcohol. PB-AT Final Report No. 499; Joint Intelligence Objectives Agency, Washington, D. C.
16. Saeman, J. F. 1947. Aerobic fermentor with good foam-control properties. Indus. & Eng. Chem., Anal. Ed. 19: 913.
17. Kiefer, F. 1947. OTS, PB 85158, U. S. Dept. of Commerce, Washington, D. C.
18. Anon. 1957. The Pharmacopeia of the United States of America, 15th Revision (USP XV), First Supplement, Washington, D. C.

Utilizing Lignosulfonates

FROM SPENT SULFITE LIQUOR[1]

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Lignosulfonates are the main component of spent sulfite liquor—50 to 60% of the dry solids. Food-grade vanillin is the most successful cleavage product, but a large market for intermediates in the chemical fields has not yet materialized.

IT IS NOW ABOUT 90 YEARS since digestion with bisulfite and SO_2 was established as a technical process for producing cellulose fibers from wood. This development, apparently carried out independently and at the same time by Tilghman in the United States, Ekman in Sweden, and Mitscherlich in Germany, has had tremendous influence in modern civilization. Considering the multitude of important uses for cellulose today—paper and board—regenerated cellulose fibers and sheets—chemical conversion into esters and ethers—it is hardly possible to speculate how today's life would be without this unique polymeric material, so abundantly available and replenishable by nature's photosynthesis.

The sulfite pulping process was discovered with only meager knowledge of the chemistry of the wood components. In this process, cellulose, being the most resistant component, remains undissolved and therefore is conveniently segregated while the so-called "incrusting materials" become soluble in the digesting process and are easily washed away from the liberated cellulose fibers.

Today's situation remains much the same for most of the sulfite mills in that about 50 per cent of the wood substance, dissolved in the spent cooking liquor in liberating the cellulose fibers, literally "goes down the drain." This represents a tremendous waste, probably the largest of any industrial operation today. It is estimated that in the United States some 3,000,000 tons of wood components go to waste each year in the discarded spent sulfite liquor.

Research on the chemistry of the wood components during the last 30 years has contributed very substantially to the understanding of the sulfite pulping process and the nature of the process effluent. As research continues to furnish additional insight, a more extensive and effective utilization of the major wood components will result. Two important factors to promote such developments:

1. The ever-rising cost of wood increases the economic necessity for its more complete and practical utilization.
2. The innocuous disposal of organic industrial wastes is becoming an increasingly unavoidable obligation.

Spent Sulfite Liquor Evaporation

The seemingly simple procedure of recovering the spent liquor solids by evaporation has presented serious technical as well as economic problems. The liquor is acid and highly corrosive, and contains scale-producing calcium salts, which reduce heat transfer. Today, specially designed stainless steel evaporators are available to solve the technical problems. However, since the feed liquors to the evaporators contain only 10 per cent solids, the heat balance on burning the concentrated liquor is generally unfavorable as compared with American fuel prices.

A newly developed process that efficiently reclaims the heat value of dilute solutions of organic matter may prove of importance for spent cooking liquor utilization. In this process, the spent liquor from the digester is treated without prior evaporation at elevated temperature and pressure with a sufficient amount of compressed air to give complete combustion of the organic matter. The heat of combustion produces steam which, together with the high-pressure non-condensable gases, can be converted into energy in excess of what is required to operate the oxidation.

The liquor concentrated by evaporation (or the corresponding product in dried powder form) represents a crude, low-cost raw material that is marketed in increasing quantities and for a multitude of uses.

Spent Sulfite Liquor Composition

The composition of the spent sulfite liquor varies considerably with both the cooking process and the species of wood used. It is characteristic of the complex nature of the spent liquor problem that, even with today's analytical techniques, it is impossible to arrive at the exact qualitative or quantitative composition of these liquors.

The two main components in spent sulfite liquor are carbohydrates and lignosulfonates. The carbohydrates originate from the hemicellulose of the wood, and are mainly present as monosaccharides. Since the sugar components are readily identified and their properties are well known, it is natural that the earliest and some of today's most extensive uses for spent sulfite liquor relate directly to the sugar components. Some of these developments were presented in other papers at the 12th National Meeting, and are therefore not further discussed here.

Lignosulfonates

Lignin is the second largest constituent in wood. It is assumed to function physically as the gluing component, holding the cellulose fibers together. It is the main product that must be dissolved in pulping in order to liberate the cellulose fibers. The lignin is solubilized in the sulfite process by sulfonation and acid hydrolysis.

In the spent sulfite liquor, lignosulfonate is the major component, comprising from 50 to 60 per cent of the dry solids. Most efforts to utilize spent sulfite liquor have been directed to finding industrial uses for lignosulfonates or products derived from them. Actually, more uses have been considered and proposed for lignin products than for cellulose. As a result, the scientific, technical, and patent literature in this area is indeed becoming very voluminous.

[1] Presented at Session XV, Chemical Utilization (2), FPRS 12th National Meeting, June 22–27, 1958, Madison, Wis.

The Author: J. Richter Salvesen was educated in Norway, and came to the US in 1927 on a fellowship to study pulp and papermaking. He has been in research at Marathon since 1930.

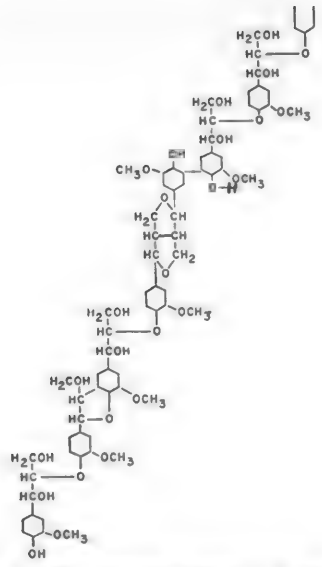

Fig. 1.—The structural elements of lignin, as postulated by Adler.

The very extensive research of past years to establish the structure and chemistry of lignin and lignosulfonates is still far from completed. It is now recognized that lignin is a large molecular structure built up by complex condensation of phenylpropane units in a manner comparable to that of cured Bakelite resins.

Fig. 1 is probably the most up-to-date proposed picture of lignin. Professor Adler, who proposed this formula in 1956 as being consistent with the behavior and reactions of softwood lignin, said about it: "This picture is not supposed to be a structural formula in the proper sense. Rather it is to be looked upon as a kind of panorama of scenery on a somewhat hazy day, when the more prominent features of the view can be distinguished, whereas other details may be hidden from our eyes or appear unsharp, in a scattered light. As a whole, however, lignin need no longer be classified as terra incognita."

When lignin is sulfonated in the sulfite pulping process, sulfonic groups attach to the aliphatic side chain, mainly, and perhaps exclusively, to the alpha carbon. In this way every other or every third propyl guaiacyl unit is sulfonated during the pulping process. In order to liberate the sulfonated lignin from the wood structure, it must be hydrolyzed by the acid cooking conditions. This results in water-soluble lignosulfonates in the spent cooking liquor with molecular weights ranging from several thousand to around 50,000.

Simple Cleavage Products From Lignosulfonates

When lignosulfonates are digested with alkali at elevated temperature, cleavage products are formed. Some of these are identified as simple aromatic compounds, namely vanillin and acetovanillone—the latter to the extent of 10 per cent of the vanillin. This development was one of the important proofs of the partially aromatic nature of lignin (Fig. 2).

From the early test-tube experiments of 30 years ago when vanillin was detected by odor only, improved factory-scale processes have been developed so that, today, almost the entire vanillin flavor market, some one million pounds per year in the United States, is supplied by pure, food-grade vanillin produced by the alkaline cleavage of lignosulfonates. This evidence that pure, crystalline aromatic compounds can be derived from the abundantly available lignosulfonates raised hopes that this conversion might lead to large market outlets as intermediates in chemical industries, for plastic, fabrics, dyestuffs, and so forth. This has not materialized since the yield of vanillin and similar cleavage products from lignosulfonates is very low—actually less than 10 per cent—and processing costs, particularly for chemical reagents, necessitates selling prices that are unacceptable for chemical intermediates. Perhaps future research will provide cleavage processes by which most of the aromatic nuclei in lignosulfonates can be segregated at low cost for resynthesis in the chemical industries.

Tanning Agents From Lignosulfonates

The oldest and still most widely used tanning materials are a class of plant products derived as water extracts from leaves, nuts, bark, and some types of wood. These extracts are referred to as "vegetable tannins"; most of them are imported to this country. Since spent sulfite liquor is also in a sense a vegetable extract, it is not surprising that one of the first industrial uses for such liquor was in tanning. With the economic advantage of being abundantly available—in war as well as peace time—and at considerably lower costs than vegetable tans, spent sulfite liquor and numerous refined products derived therefrom have been, and still are, extensively used as auxiliary tanning agents all over the world.

Scientific studies on the tanning process have clarified both the benefits and the limitations of spent sulfite liquor. It is now known that the lignosulfonates combine with the basic amino groups through salt linkage in the hide substance. This is a useful function in the tanning process, but not sufficient to provide fully tanned leather. The lignosulfonates as they exist in spent sulfite liquor are deficient in other chemical groupings that are needed to produce fully tanned leather. With the clearer understanding of tanning process requirements and of lignosulfonate chemistry, it is now possible to develop modified lignosulfonates with leather-making qualities comparable to vegetable tannins, but they have not yet been practical from an economic standpoint.

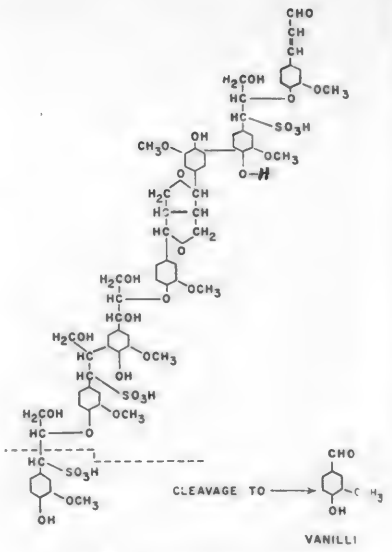

Fig. 2. —Sulfonated lignin.

Dispersing Agents From Lignosulfonates

Lignosulfonates, because of their molecular size, shape, and active groupings, have potentially valuable surface-active properties. The science of physical chemistry is producing knowledge that explains the numerous phenomena relating to chemical and electrical activities of surfaces. These phenomena are encountered not only in industrial processing but in many activities in man's everyday life. The knowledge and development of surface-active agents is therefore acquiring increasing significance, and it is certain that lignosulfonates in suitable modifications have large and promising market possibilities in this field.

Dispersing action is the surface-active property that prevents finely divided particles in suspension from agglomerating by providing electrically repelling forces. This, in turn, retards and prevents settling of insolubles in water suspension, reduces the viscosity of a suspension with a given solids content, and permits increased concentration of solids in suspension without an increase in viscosity.

The high-molecular-weight lignosulfonates with strongly ionized sulfonic groups are recognized by the physical chemistry term "anionic polyelectrolytes." Such compounds provide cas-

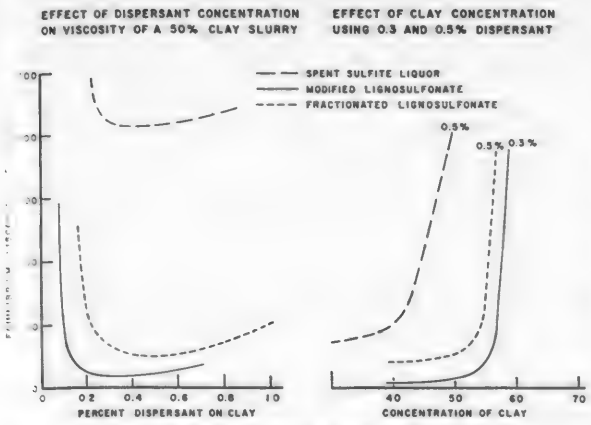

Fig. 3.—Dispersion of ball clay.

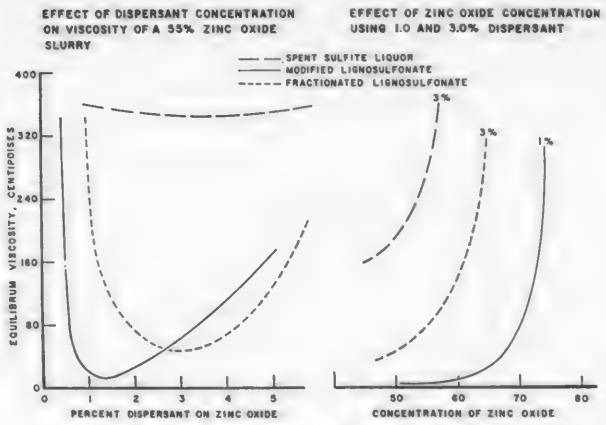

Fig. 4.—Dispersion of zinc oxide.

persing effect by being absorbed on finely divided solid particles and thereby imparting a negative charge to them.

A list of typical industrial applications presently served by various types of lignosulfonate dispersants is given in Table 1.

The lignosulfonates vary considerably in their dispersing properties. Variations on the purity, degree of sulfonation, molecular size, and other incompletely understood factors. Dispersing efficiency is evaluated by measuring the viscosity of the dispersed system, and, from an economic standpoint, by the amount of dispersant required to maintain a desired fluidity. This is illustrated by the following examples in which the efficiency of spent sulfite liquor, fractionated lignosulfonate, and modified lignosulfonate for dispersing suspensions of clay (Fig. 3) and zinc oxide (Fig. 4) is compared.

The optimum amount of dispersant required to achieve maximum dispersion is determined by systematically varying the amount of dispersant while the concentration of the dispersant remains constant. It is usually found that definite optimum concentrations of dispersing agents exist, and to achieve the best results these optima should be recognized. The highest solids content of dispersate that can be obtained is then determined with the optimum concentration of dispersant.

When no dispersing agent is present, both the clay and zinc oxide systems are plastic at the concentration studied, so it is quite evident that all three agents exert considerable dispersing action. The superiority of the fractionated lignosulfonate and the modified lignosulfonate over spent sulfite liquor is demonstrated both by the greater fluidity of the suspension at a given dispersant concentration and by the much higher solids concentration that can be maintained in suspension with low viscosity. This order of effectiveness points out the important fact that the utilization of spent sulfite liquor may require either fractionation or modification of the lignosulfonates, or both. Usually, many other factors are involved in dispersed systems, such as pH and amounts and kinds of other electrolytes present, and these conditions may in turn reflect on the effectiveness of the dispersant and the type of lignosulfonate that gives the most desirable effect. Thus there is no universal dispersant for all dispersing problems.

Table 1.—INDUSTRIAL APPLICATIONS FOR DISPERSANTS

Brick and ceramics	Carbon black
Cement	Dyestuffs
Gypsum and gypsum board	Mineral beneficiation
Insecticides	Foam stabilization
Oil well drilling	Wax sizing emulsions
Industrial cleaners	Foundry extrusion
Boiler water treating	Asphalt emulsions
Iron Oxide	

The inherent tendency for lignosulfonates to produce and stabilize foam is a deterrant for some applications. Even more detrimental in some cases is the dark color of the lignin dispersants. This excludes them from uses as dispersants in paper coatings and for pitch dispersion in bleached pulp. These limitations are insignificant, however, in view of the many applications where the lignin dispersants have proven of eminent importance in numerous industries. It can safely be predicted that the market for such dispersants will grow steadily along with the increased recognition of the need for dispersants and the development of improved lignosulfonate products.

Summary

The sulfite pulping process as operated today is leaving a tremendous quantity of wood constituents going to waste, as contained in the spent cooking liquor. This challenge to the industry and to basic as well as applied research is gradually being met with more and larger industrial applications for lignosulfonates.

As surface-active agents, these compounds in suitable modifications will find increasing market outlets. The complicated structure and reactivity of lignosulfonates have as yet prevented the large-scale use of these compounds as raw material for conversion into simple aromatic products with which to supply the synthetic organic chemical industry. It remains for research and creativity to materialize in the future many of the potential values we today are looking for.

Discussion

Paul D. Haigh (Komarek–Greaves & Co.): Is a serious attempt being made to remove objectionable odors when sulfite liquor is used as a charcoal briquet binder?

Dr. Salvesen: I am not aware of serious efforts to remove the odor. Unless anaerobic conditions can be maintained, this shows little promise.

Dr. A. S. Gregory (Weyerhaeuser Timber Co.): What is the nature of the modification used to improve dispersing power of lignin liquor solids?

Dr. Salvesen: This is done by altering the molecular weight. The alteration depends on the type of action required. The degree of sulfonation and type of ions, cations or anions, are important. The patents disclose the nature of the modifications.

Carter A. Watson (Puget Sound Pulp & Timber Co.): What is the nature of the modifications used to make lignosulfonates better tanning agents?

Dr. Salvesen: Phenolic groups and carboxylic groups have improved the tanning properties. This may involve synthesis, which increases the cost beyond cost of other tannin materials. There are no good ways to characterize these compounds.

Exterior Finishes for Wood . . .

SOME OF THE PROBLEMS INVOLVED

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The wood itself and methods of construction contribute to many paint failures. Since all paint films will fail eventually, the dual goals of a good paint are long life and a surface suitable for repainting.

THERE ARE FIVE MAJOR FACTORS that are critical in determining the serviceability of exterior paints on wood:

1) The kind and quality of wood.
2) Proper structural design to keep the wood dry enough to hold paint.
3) The composition and quality of the paint.
4) Conditions and technique of application and program of maintenance.
5) Variations in severity of local exposure.

Of these, only the first four can be controlled and are also interdependent in their effect on paint performance. While the last variable is not directly controllable, proper paint formulation and choice can minimize the severity of local climates.

To review the first two factors, briefly, one can say that proper design of a building, which would logically include proper choice of wood type, will protect against the entrance of moisture behind the painted wood surfaces. This involves the usual provisions of proper sheathing, flashing, moisture-vapor barriers, and so forth, as well as provision for adequate ventilation of interior-derived water vapor. The kind of wood may reasonably vary with the sources available and effects intended, but the quality must be adequate for suitable performance. These factors are properly the province of the builder-architect-owner team, and are all determined before the wood surface is ready to be painted. The type of construction will determine the type of paint that will be used, and the choice of paint should be as much a matter of engineering as the foundations.

Certainly, proper methods of construction are known and available to the building industry, and the only comment that may be pertinent here is that it is surprising how often paint problems arise from apparent lack of good practice.

A great deal of information and experience are available on the behavior of various wood types, both from the excellent work of the U.S. Forest Products Laboratory, the Forest Products Research Society, and the various commercial and technical bodies of the paint industry. This knowledge is derived from long experience with the performance of paints on innumerable buildings in many areas, on very extensive and controlled testing of paints on various woods on test fences, and, in somewhat more limited instances, on valid laboratory tests. Thus, it is taken for granted that softwoods are most suitable as paint-holding woods for exterior surfaces, and that durability of paint generally depends on the specific gravity of the wood upon which it is applied, being best for woods of low specific gravity. (However, it is not always recognized that, even within a wood species, specific gravity may vary sufficiently to affect seriously the paint-holding power of individual boards.)

It is also known that the manner in which wood grain is exposed by sawing affects the ability of paint to adhere to the wood and, thus, ultimate durability; and that other factors such as the presence of extractives in wood, moisture content at time of painting, type and number of wood defects, and the changes in dimensions of wood that occur with moisture are of influence, also, in paint performance.

It should also be recognized both by the forest products industry and the paint industry that the majority of softwood lumber produced is not the best for paintability. Thus, in 1947, only 10 percent of the softwood lumber milled was rated as being in the most desirable class for paint retention. This includes such woods as redwood, cedar, cypress, and white and sugar pine; 67 percent of the lumber produced was from much less desirable species such as Douglas-fir and yellow pine. Accordingly, it behooves both industries to develop products that will allow the use of the more abundant but less suitable types of woods and still give adequate performance.

Paint Failure Draws Criticism on the Paint

In the usual case, however, by the time a structure is to be painted all the above factors have either been considered or neglected, and the paint system must be applied to whatever surfaces exist and must give satisfactory performance. If failure should occur, the paint usually is blamed, whether or not it was at fault, since it is the component that has most obviously changed. In view of this natural, tendency to lay the blame on the obvious aspect of failure, the paint industry has had, in self-defense, to spend much time and effort in recognizing hidden causes of failure, other than the paint itself, and in developing solutions to problems presented by various short-comings in the methods of construction and woods used in building. It will be the purpose of this paper to discuss some special problems of this sort and the current solutions being used by the paint industry.

It would be appropriate at this point to consider some general aspects of

[1] Presented at the Spring Meeting, Northern California Section of FPRS, May 1–2, 1958, Berkeley, Calif.

The Author: Neil Estrada holds BS and MA degrees from the U. of California, and a MS from Calif. Institute of Technology. In addition to his position as supervisor of research and development, he is chairman, tech. committee, Golden Gate Paint & Varnish Production Club.

paint performance of wood surfaces. It is recognized that some woods will withstand weathering for very long periods of time, but the appearance of such unprotected surfaces is so unattractive in the usual residential surroundings that most exterior wood surfaces are painted, even though it must also be recognized that organic coatings are quite limited in durability.

The first, and vital, function of the paint film, therefore, is to protect the wood surface from the effects of weathering, which is achieved primarily by excluding moisture and shielding against the influence of light on the structure of the wood itself. This is customarily obtained by suitably pigmenting a binder such as linseed oil with a mixture of opaque pigments. The pigments exclude light from the wood, and the binder protects the wood from readily absorbing moisture. At the same time, the pigment and binder mutually reinforce one another to provide longer protection for the wood. The binders, being organic in nature, as is the wood substrate, are subject to attack by weathering, and the paint will eventually fail in its ability to protect the wood. Proper pigmentation will prolong the life of the film by minimizing the influence of light and reducing the effect of moisture on the film itself, and will also so influence the type of film failure that a suitable surface is presented for repainting.

Since the paint will eventually wear away and require repainting, the economics of painting requires that each paint job must last as long as possible. All too frequently, however, paints are purchased on a cost-per-gallon basis rather than on the cost-per-square-foot-per-year-basis. The use of inferior and cheaper paints can never be justified if performance and ultimate low cost of durable protection is considered. Many studies attest to this, and it is the combined responsibility of the building and paint industries that such fraudulent materials are used and give rise to justifiable complaints on the products of both industries.

Paint as a Decorative Coating

The other important function of paint is that of being a decorative coating. It is this function that often determines the choice of paint both with respect to color and type, especially by the individual home owner, who generally takes paint quality for granted. This is the most obvious visual aspect of paint, and here retention of whiteness or color and gloss characteristics are of importance. With the advent of brighter and deeper colors in exterior paints, problems arise in the formulation of paints that must be applied to the non-uniform surface presented by wood and still present a uniform paint surface.

Some of the special problems presented by wood and wood construction methods can now be examined in regard to how they affect paint performance and the approach of the paint industry toward their solution. The general problem of durability, in itself, is a very important one, since to increase the average life of exterior paint systems by one year would be a major achievement. Progress in this direction has been rather slow, and few major changes have occurred since the shortage of linseed oil during World War II caused a reassessment of the relative amounts of pigment and oil necessary to provide durability. Current conventional house paints are based on suitable combinations of raw and bodied linseed oil with pigment mixtures that consist of titanium dioxide, zinc oxide, lead, and extender pigments. Progress has been mostly limited to developing better pigment combinations, which have emphasized the role of titanium dioxide versus lead and proper choice of extender pigments. Achievement of the so-called "one-coat house paints" is one result of this progress. In general, only minor improvements are likely to come from further work on pigmentation.

Earlier attempts to improve paints by utilizing other and better binders than linseed oil in the raw and bodied forms were mostly unsuccessful. Efforts to utilize the widely recognized durability of alkyd resins did not prove fruitful until very recently. Indications now are that a major step forward in improving house paints may be possible through the use of a new variety of alkyd resins based on a new chemical, isophthalic acid. This material, available commercially only since 1957, allows preparation of alkyd resins that resemble bodied oils in viscosity and at the same time exceed bodied oils in dry speed, mildew resistance, gloss retention, and durability.

Early development work back before 1950 established the unique properties of what are termed very long-oil isophthalic alkyds, and indicated their possible use in house paints. Initial test-fence results were so promising that, as soon as pilot quantities of raw materials were available, full-scale house tests were begun. These tests, which covered hundreds of houses in all sorts of Western climates, resulted in the conclusion that much improved house paints were possible. It was found that the better durability gave much better gloss retention and much less chalking, which thus allows colors to remain brighter and fresher. Better drying speed made for less dust collection and less sensitivity to fog and dew. application properties, also were entirely satisfactory.

Although this development was compressed into a period of about eight years, the results were so impressive that the major West Coast paint manufacturer has changed its entire line of exterior house paints to an isophthalic base. An interesting point is that one of the raw materials used in this new type of resin, tall-oil fatty acids, is a by-product of the forest products industry.

Much home construction in the past decade or more has been of the ranch-type or so-called "flat-top" type of home where rough texture on the wood surface has not been objectionable, but rather desireable in order to avoid too much of a painted look. The use of much low-grade lumber for tract homes also provides surfaces that are difficult to paint satisfactorily with conventional house paints. since the rough surface and non-uniform porosity show up in streaky gloss and spotty color. The trend toward deeper body colors on houses also tends to magnify deficiencies in wood surfaces.

The obvious solution to these problems was to use glorified shingle stains that do not build good oil films. These had very limited durability, however, since they tended to fade, gave uneven color, and required too frequent repainting. Testing of another form of alkyd resin, the very high-viscosity, low-solids type normally used in interior flat wall paints showed that exterior flat house paints could be formulated to give excellent service in this type of application. Because of the non-penetrating character of these resins, uniform color and no gloss could be obtained even over woods that showed extreme differences in porosity. The durability of the properly pigmented paints maintained the color and film integrity for much longer periods and provided more suitable surfaces for repainting. By utilizing these superior flat alkyd house paints, the home owner can now be sure that his flat paint will give performance comparable to conventional house paints.

Blistering Involves both Wood and Paint

Another problem that involves both wood and paint is that of paint blistering. If wood is too high in moisture when painted, it is quite likely to give

rise to a blistering type of failure, where the film is detached from the wood. The same sort of failure can occur if the wood becomes wet after it is painted, usually from improper construction or lack of proper maintenance of the structure, such as allowing gutters to clog and overflow. Areas where rain is prevalent show more problems of this type, but the difficulty can arise anywhere. To aid in minimizing this trouble, special "blister-resistant" paints have been developed that will give satisfactory performance on many otherwise troublesome surfaces. The development of this type of paint has been well described; the papers given by D. F. Laughnan (U.S. Forest Products Lab.) and W. G. Vannoy[2] at the FPRS 11th National Meeting in Buffalo, covered the current status of the problem rather well. It should not be assumed, however that any paint will overcome completely the effects of moisture under aggravated conditions. The ultimate solution to this problem of blistering has yet to be developed and to a large extent it must be dependent on better choice and use of wood.

It appears likely that application of paint to wood surfaces at the mill will continue to grow rapidly in the future. It is being practiced now on some reconstituted wood products, and will probably extend to regular lumber. It has been done for some time in the shake industry. While there are diverse reasons for applying paint at the mill, such as upgrading hardboard, improving the saleability of a product by reducing the amount of effort in finishing, and so on, the problem of developing suitable finishes that can be applied at the mill satisfactorily and still perform adequately in the final use is still only very partially solved.

Except in the case of shakes, mill coatings are usually primers or sealers, designed to be coated later with some suitable finish coat. The end use of the wood and its final coating will necessarily determine the type of paint used in the mill. For wood products used for interior applications, the primary requirement is adequate sealing so that subsequent paint coats are properly held out; this can be achieved with little concern for durability. A prime coat for lumber to be exposed on the exterior of buildings, however, must meet much more critical requirements. In addition to being adaptable to mill application, it must not detract from the ultimate durability of the finished paint system.

[2] Vannoy, W. G. 1958. Blister- and Stain-Resistant Paints. Forest Prod. J. VIII (1): 17-A.

The question of obtaining finishes that will be practical in drying time at the mill and still meet the end-use requirements of the coated wood is the key to successful mill coating. In the cases of the shake industry, where the coating applied is also the final finish, the problem of drying speed has been met by utilizing the porosity of the wood to absorb the binder, typically linseed oil in some modified form. This leaves a relatively dry surface that can be handled and packed. This technique also means that the finishes applied are not nearly so durable as could be desired, and the end product usually requires further painting a year or so after it is exposed. In areas of high sunshine, these stains degrade very rapidly and this has limited the use of pre-finished shakes in certain areas.

Currently, the problem of durability of the shake paint is being met by the use of a suitable poly (vinyl acetate)–based paint, which dries and forms its film by the loss of water, and which also provides a much greater degree of durability in the finished paint. In addition, since it is a water-dispersed resin, fire hazards from volatile thinners and combustible oils are eliminated. The fire hazard from oils and thinners used in conventional paints is certainly a factor of critical concern in mill finishing.

Treatment of the various reconstituted boards, hardboard and particleboards, at the mill is becoming necessary to allow them to be of adequate utility and to compete in their final usees. In the case of hardboards, as exemplified by Masonite, an oil tempering process has been widely used. More recently, efforts at sealing these materials with pigmented finishes have been relatively successful. Here again, the use of suitable water-based emulsions gives superior performance in sealing and provides a bonus in lack of fire hazard. Economically, these emulsion finishes are competitive because of their greater sealing efficiency. While the extension of mill coating to lumber for exterior use will undoubtedly develop, the relatively slow drying of conventional oil-type primers will retard progress in this respect.

It is entirely possible that this problem also will be solved by the development of suitable emulsion-based coatings. The many desirable properties of paints based on emulsion polymers, such as quick drying, excellent sealing, durability, low cost, and versatility, make this approach very attractive.

The final problem to be discussed is perhaps the most difficult of all that face the paint industry: the problem of coating and protecting wood surfaces in such a way that the color and grain characteristics of the wood itself are visible and maintained over a suitable interval of exterior exposure. This can be described as the problem of developing suitable clear coatings for wood that must be exposed to the forces of weather.

The Technical Committee of the Golden Gate Paint and Varnish Production Club made a two-year study of this problem, and it was reported to the Buffalo meeting of the FPRS. Following is a summary of the results of this study, and a description of further work that is being undertaken in direct cooperation with the California Redwood Association.

Some 26 different resins were exposed, including oils, modified oil varnishes, alkyds and latices, these covered the range of materials considered as being suitable for the purpose. Certain selected resins were further modified with special additives such as fungicides, light-stabilizers, iron-oxide-pigmented first coat, colloidal iron oxide, and silicone resin modification, and the wood substrate was varied from the usual redwood with red cedar and white pine. In all some 78 panels, 2 feet by 6 inches by ¾ inch, with two- and three-coat systems on both sides of the panel, were exposed in a vertical position. Exposure sites were Cloverdale, Cal.; Long Beach, Cal.; Tulsa, Okla.; Portland, Ore.; and Sayville, Long Island, N. Y.

The results can be summarized as follows:

1. Exposure site had a large influence on relative durability, with Cloverdale being much the severest and giving an accelerated test result that corresponded to failures obtained later in other areas. Climates like Portland and Sayville are least severe and allow use of less durable coatings.

2. Three-coat systems are necessary on new wood.

3. Evidence indicates that inclusion of mildewcides in clear finishes may decrease their ultimate durability.

4. Ultraviolet-light-absorbing agents appear to have a positive effect on durability.

5. The use of small amounts of iron oxide in the first coat gave the most promising results in maintaining durability. This technique can be utilized on both redwood and red cedar, since the pigment color is not noticeable on

[3] Estrada, N. 1958. Exposure characteristics of clear finishes for exterior wood surfaces. Forest Prod. J. VIII (2): 66.

hese woods and actually helps to pro- ide a more uniform appearance.

6. Use of a colloidal iron oxide is f questionable value.

7. Red cedar gives as good durabil- as does redwood, but white pine is uch less satisfactory as a substrate.

8. Silicone resin modification results i- less durability.

9. In the more severe climates, the rious oils and varnishes were inade- ate, as were the latex types exposed. Epoxy varnishes also failed rapidly, as d some special silicone varnishes.

10. The alkyd resins generally gave t e most satisfactory performance as f r as durability was concerned, in all l cations. The best of those tested were a conventional long oil, soya alkyd, very commonly used in architectural enamels, and a somewhat longer oil isophthalic acid resin. However, ultimate failure of those films tended to be by delamination rather than by erosion, which would present a difficult surface for repainting if they were allowed to reach the failure stage. It was quite marked that changes occurred in the wood structure beneath these durable films that degraded the wood to such an extent that the adhesion of the film was seriously impaired, thus shortening the life of the coating.

As a result of these findings, the Production Club Technical Committee, in conjunction with the California Redwood Association, is continuing this exposure work at the Cloverdale location. Further exposures will be made on the most promising systems developed to date, with suitable combinations of the additives already examined and others that may be suggested.

Methods of modifying or influencing the wood surface, itself, will be tested since this appeared to be an important factor in failure. A cross section of various catalyzed finishes, which were excluded from the first test series, will be examined. These will include catalyzed epoxy resins, polyesters of various types, urethane coatings, both air-dry and catalyzed, and others that may be suggested. Further testing of latex types should be included in view of the lack of experience on formulating this sort of resin for clear wood finishes. As always, in exposure work, the big problem will be to restrict the number of panels and still adequately test all variables possible. Any suggestions, especially with respect to methods of modifying the wood surface prior to painting, would be sincerely appreciated.

STATISTICAL BASES FOR

Quality Control Charts[1]

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Two Rivers, Wis.

The average and range chart is applicable wherever measurable variability is a problem. The concept of variation and its statistical implications are presented, and the measurement of this variation is tied in with average and range charts and their interpretation.

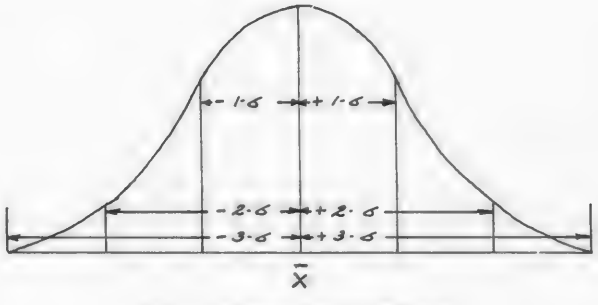


Fig. 1.—A normal variability curve.

Basic to an understanding of statistical quality control is a knowledge of the nature of variation. Variation can be most easily explained and understood in terms of dimensional variations. In studying variation, one must consider the form of data for measurements or information that can be obtained. Data can be of two general types: it can be in terms of attributes such as white or black, or it can be in terms of measurements or variables. This paper is concerned with the latter, although there are control charts for both types of data.

When planing lumber, it is impossible to set up a planer to plane exactly one inch and expect all boards that go through the planer to be exactly one inch thick. Some old planer hands call it perfect when they can take a folding rule or gauge with a one-inch notch and measure the parts, and can detect no variation. But with a good micrometer caliper, there may be readings from different places on one board from 0.985 to 1.015 inches. This shows that it is possible to detect variations in everything with the use of suitable measuring tools.

The Author: Edward Hansen is quality control statistician at Hamilton. He graduated from St. Olaf College, Minn., in chemistry and math, and joined Hamilton in 1954.

[1] Presented at Session IX, Quality Control, PRS 12th National Meeting, June 22–27, 1958, Madison, Wis.

Normal Variation

Most cases of variation fall into a classification called "normal variation". Examples include most machining operations to produce a desired dimension, intelligence quotients of a large population, heights of a large group of people, and a whole host of other examples.

From the statistical quality control angle, the important thing about normal variation is that any population can be described uniquely by just two statistical measurements or values. These are the arithmetic mean and the standard deviation.

Average, Standard Deviation, and Normal Curve

The arithmetic mean or average, as it is commonly called, is merely the sum of all values in the population divided by the number of items included in the population. For example, the following values for the ages of a group of children:

6
6
7
10
7
7
9
4
Sum = 56

$$\text{Average} = \bar{X} = \frac{\Sigma xi}{n}$$

$$\bar{X} = \frac{56}{8}$$

$$\bar{X} = 7$$

xi = individual values
n = number of cases
Σ = sum of
$\bar{X}$ = average

This is very elementary, of course. The average is the most representative value of a group of numbers, or it can be thought of as the central value, intuitively.

Standard deviation is not so simple, familiar or intuitive. It is actually the root mean square of the deviations of the values from the arithmetic mean. It is, to put it simply, a measure of dispersion, spread, or variability. Fig. 1 is a graphical representation of a normal curve.

The normal curve has, in general, the following six properties:

1. The maximum ordinate always is found at the average position in the curve.
2. The normal curve is symmetrical around the average value.
3. The curve falls rapidly toward the X axis in either direction from the average value.
4. There are two points of inflection when the curve changes from being concave downward to concave upward. They occur at $\bar{X} + 1\sigma$ and $\bar{X} - 1\sigma$ position in the curve.
5. The total area under the curve is one unit. (For an explanation of this, see any advanced statistical text.)
6. The probability of occurrence of any random value lying in any interval is the area under the curve between the ordinates that describe the interval.

The standard deviation can be thought of as the distance along the horizontal axis such that plus or minus one standard deviation from the mean will include 68.26 percent of the cases; plus or minus two standard deviations from the mean will include 95.46 percent of the cases, and plus or minus three standard deviations from the mean will include 99.73 percent of the cases.

The measure of variability aids in the interpretation of individual numbers in relation to the average. For example, if the length of a board is 100 inches and the average of a sample of 100 of these boards is 90 inches, it is impossible to determine whether 100 is exceptionally large or is just one of the more average values. But if it is known that the standard deviation is two inches, then it is obvious that 100 inches is five standard deviations above the mean. With this knowledge, it is possible to evaluate what a board 100 inches long means. Standard statistical tables[2] for areas under the normal curve show that the probability of getting a value five standard deviations away from the mean in a controlled process is about .0000006. It is now possible to interpret what this individual value means in relation to what is known about the distribution. This illustrates the beauty of the normal distribution.

However, plus or minus three standard deviations from the mean will include 99.73 percent of the cases only when the operation in question is affected only by random, chance, unassignable causes. These would include inherent machine variability, normal wear in cutting tools, temperature variations, material variations, and so forth. When an assignable cause becomes operative, the process may produce parts at a distance from the mean greater than plus or minus three standard deviations more often than would be expected.

In the industrial situation, unfortunately, the standard deviation is too difficult and time-consuming to calculate. Statisticians have developed a simple approximation to the standard deviation by means of the statistic called the "range".

The "Range"

The range is simply the lowest value subtracted from the highest value, or the distance between the lowest and highest values. It is another measure of variability. The range calculation is illustrated below.

[2] Burr, I. W. 1953. Engineering Statistics and Quality Control. McGraw Hill Book Co., Inc., New York.

Terms Used

$\bar{X}$ = Average, or more exactly arithmetic mean.
n = number of cases or values.
σ = standard deviation of a set of numbers.
R = range, the difference between the largest and smallest values in any set of numbers.
$\bar{R}$ = average range of a group of ranges.
d_2 = a factor that is a function of N and expresses the ratio between the expected values from a large number of samples from a normal distribution and the standard deviation of the distribution.
A_2 = a multiplier of $\bar{R}$ to determine the distance from the control line to three σ control limits on the chart.
D_1 = a multiplier of $\bar{R}$ to determine the three σ upper control limit on a R chart.
K = number of samples.
$\bar{\bar{X}}$ = grand average of a group of averages.

Sample of six values

5
6
7
10
3
12

The range of the sample is 12 − 3 = 9

By dividing the statistic called the average range of a group of samples taken from a distribution by a constant d_2, the standard deviation of this distribution can be determined.

$$\text{Standard deviation} = \frac{\bar{R}}{d_2}$$

In statistical quality control, the actual goal is to gain reasonably accurate information about a population of large size by taking a series of samples of small size and analyzing them statistically. Now that some of the important statistical measures are defined, how they dovetail to form the control chart for measurements must be explained.

Average and Range Control Chart

The underlying basis for using control charts is the fact that any production system that produces an item such as a piece part with various dimensions (whether the dimension is measured in feet, inches, pounds, etc.) forms a normal distribution of these measures if chance causes alone are present. Previous discussions of variability showed that the probability is very high that very few points will fall outside the band described by the average plus or minus three standard deviations from the average of the distribution. This is the band of normal variability that is experienced when chance causes alone are at work. When a point

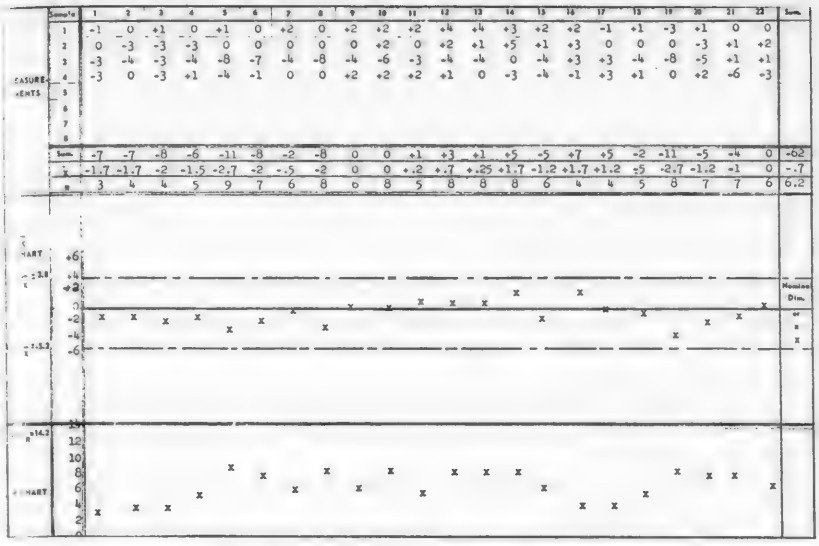


Fig. 2.—A typical average and range chart.

goes outside of this band, the probability is very high that something happened to the process to produce this point. The process has gone out of control because of some assignable cause, and should be investigated.

Assignable Causes: Dr. Burr in his book ENGINEERING STATISTICS AND QUALITY CONTROL[2] says that there are, in general, six types of assignable causes that are of primary concern:

1. Change in process average. These are sudden, more or less drastic, changes in process level, measured by the average, such as a change in material, chipped or broken tools, or something of this nature.
2. Change in process variability. These are changes in variability, which would show up first on the R section of the chart. This type of assignable cause could be the result of a loosening of a fastener, which resulted in increased play of a moving cutting head, for instance.
3. Change in curve shape. This is difficult to detect from an $\overline{X}$ and R chart, but if some assignable cause was operating to give every 10th piece a higher value, the end result would be similar to a change in curve shape. This is not a very common phenomena, however.
4. A steady shift. This would show up on the average section as a trend either up or down. A typical example of this is tool wear.
5. Cyclic and erratic shifts. Cyclic and seasonal shift could be due to daily, weekly, or seasonal effects, and show as a movement of the average on the average section of the chart. The erratic shifts are usually seen as out-of-control points on the average section of the chart. They are often caused by too frequent resetting of the machine.
6. Mistakes. If each point stays within plus or minus three standard deviation limits, then the process is said to be in statistical control because there is no reasonable evidence that there is an assignable cause present. Therefore, assignable causes are not sought, because the process is in control.

The choice of plus or minus three standard deviations from the mean instead of plus or minus four or plus or minus six is arbitrary to a degree, but experience has shown that it is the most economical balance between looking for assignable causes when they are not present and not looking when they are present.

Preparation of $\overline{X}$ and R Charts

The formula for the control limits for the average and range charts follow:

$\text{UCL}_{\overline{X}}$ (upper control limit on $\overline{X}$) $= \overline{\overline{X}} + A_2\overline{R}$

$\text{LCL}_{\overline{X}}$ (lower control limit on $\overline{X}$) $= \overline{\overline{X}} - A_2\overline{R}$

UCL_R (upper control limit on R) $= D_4\overline{R}$

LCL_R (lower control limit on R) $= D_3\overline{R}$

Where E = sum of
$\overline{X}i$ = individual values
K = number of samples
n = number of individual values
A_2, D_3, D_4 are control chart constants

$$\overline{R} = \text{average range} = \frac{ER}{K}$$

$$\overline{\overline{X}} = \text{grand average} = \frac{E\overline{X}i}{K}$$

Fig. 2 is a typical average and range chart. The operation described is the planing of plywood core stock to a nominal thickness of 0.578 inch. At the top of the form is where the results of each measurement are recorded. Across the top are sample numbers from 1 through 22; the rows are numbered one to eight, which refer to the sample size. Four, five and six are common sample sizes on the average and range charts. Below this is a row labeled sum, in which the measurements from the sample are totaled and entered. The next row is labeled $\overline{X}$, and is the average of the sample. The last row in this section is labeled R and is the range of the sample.

The $\overline{X}$ chart in the center of the form is merely a graph. The scale is marked with the heavy center line as the nominal dimension, and each line above or below is a certain amount above or below, depending on the scale chosen. The bottom chart is the R section, with the very bottom line the zero range, and so forth.

It is most convenient to consider the nominal dimension as zero and each value merely a certain number of units of deviation from zero. This is the way that the sample chart is often constructed, and individual values are recorded. For example, suppose the nominal dimension of an item is 2.000 inches. The sample of five is recorded as follows:

	Actual value		*Charted value*
	2.005	=	+5 (deviation unit = .001")
	2.003	=	+3
	1.997	=	−3
	1.999	=	−1
	2.000	=	0
Sum	10.004	=	+4
$\overline{X}$	2.0008	=	+.8
R	.008	=	8

Each $\overline{X}$ value and each R value is then charted on the graph. If control limits are already calculated (based on knowledge of the operation) then the control limits are merely marked in. Any value outside the control limits is cause for remedial action.

The zero line on the average chart corresponds to 0.578 inch, which is the nominal dimension. Deviations from the nominal in thousandths of inches have been recorded.

To set control limits on a process, at least 25 samples of an undisturbed process should be used to develop reasonably reliable values. The calculation of the control limits was made with the formulas given under "Preparation of $\overline{X}$ and R Charts". Examination shows that no point on either chart has exceeded the control limits. This operation is in a state of good control, and no assignable causes are present.

If an average value or range value had gone outside the control limits, immediate action would have been taken. If the control limits had been exceeded on the average, the operator

would have adjusted the set-up closer to the nominal, and then checked several cores in succession. If the value of R exceeded the upper control limit on the range chart, the operator would have checked the machine to make sure everything was tight, or would have sharpened his knives if this seemed to be the trouble.

Relationship between Average Values and Individual Values

If a process is in good control, one can be quite certain that the limit's grand average plus or minus three times the *standard* deviation ($\sigma = \frac{\overline{R}}{d_2}$) will contain substantially all the individuals in the distribution. This will enable him to compare the specifications with the natural process tolerance.

Relationship Between a Process and Specifications

A process may exhibit good control on the average and range charts, but still produce a significant number of parts out of specification. Since a good deal of data on the process should already be accumulated (one should have it before trying to solve the problem) six times the standard deviation is calculated which is the natural process tolerance spread, and this value is compared with the value maximum specification minus minimum specification.

If the natural process tolerance is wider than the specification set by the engineering department, then something drastic must be done to reduce the variability of the process, or request a widening of specifications. It is a good idea to show this by graphing the distribution as a normal curve and drawing in the specification limits, as a help in selling the engineering department on widening the specification limits.

Professor Burr[2] shows the following chart (Fig. 3), which represents six common cases of natural process tolerances and specifications with all distributions being normal.

Case a. The natural process tolerance is well within the specifications, and no trouble should be experienced as long as the operation is kept reasonably centered near the nominal.

Case b. This is an example of natural process tolerances just equalling the specifications. This is not too good, because the process must be kept exactly centered or defective pieces will be produced.

Case c. The process is centered too high, and defective parts are being produced. The process should be adjusted closer to the nominal dimension.

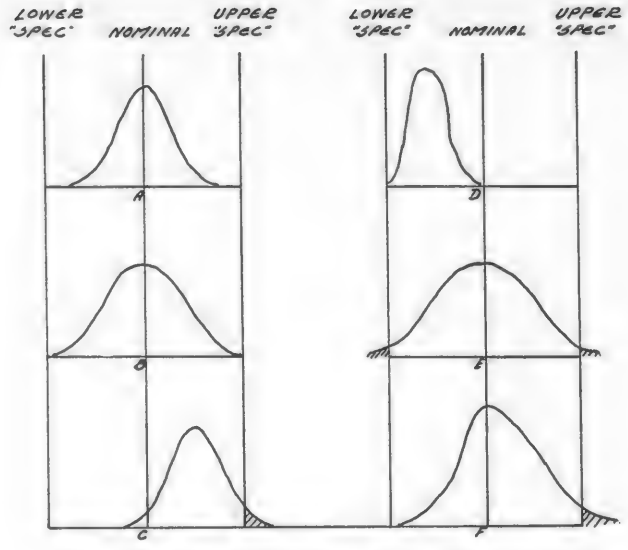


Fig. 3.—Six common cases of natural process tolerances and specifications.

Case d. This is a very nice situation in that the process tolerance is so much smaller than the specifications that there should be no trouble. In fact, the operator can start low and drift higher if there is a tool wear problem, and thus save tool dressings.

Case e. Here is a bad spot that illustrates the case mentioned before when the natural tolerances are wider than the specifications. Drastic action in the form of changes in designs or tools or widening of specifications is required.

Case f. The process is out of specifications on the high scale only. This may be the best setting for the operation, however, if an outside diameter is involved. In this case, the part can always be made smaller, but if it should fall below specifications, it must be scrapped. This would be valid only if the part cost a good deal more than the rework operation.

Discussion

John Milak (Connor Lumber and Land Co.): I gather you control these operations at the machine. How can you handle the situation where there are as many as 45 machining operations and where the operator may change the setup as many as 15 times a day?

Mr. Hansen: At Hamilton we have that situation. There are about 180 employees and 30 types of machines with quantities as low as five pieces at one time for a setup. The best way is to plot the nominal dimension as zero and deviations from zero in thousandths.

Mr. Milak: Couldn't that be controlled by checking the setup?

Mr. Hansen: Yes, if you know the variability of the machine and the machine doesn't go one way or the other, but I've never seen a machine that performed perfectly.

Mr. Milak: Is there much application of the technique where a setup is used for less than ½ hour?

Mr. Hansen: If you are doing the same operation there is.

Mr. Milak: Even if you are changing sizes every half hour on a double-end tenoner?

Mr. Hansen: If making tenons only, you are interested in dimensions between shoulders, but you may have pieces 60 inches long and others 48 inches. What you do is measure the deviation from the nominal in thousandths and control in that way.

Mr. Milak: You do that when you check the setup?

Mr. Hansen: No, as the machine is running.

Mr. Milak: Then you have to have a man at the machine all the time?

Mr. Hansen: You can have the machine operator do it, a lot of companies do. Inspectors then audit the control charts occasionally. Machine operators are paid incentives to do this checking.

A. C. Barefoot (N. C. Sstate College): The term variance was used earlier. Would you indicate the difference between standard deviation and variance?

Mr. Hansen: The standard deviation is the square root variance. Sigma squared is variance, but in quality control, we are interested in the square root of variance. This is a measure of variability or spread of the data.

BOOK REVIEW

World Timber: Trends and Prospects

THORSTEN STREYFFERT
Dean, Royal School of Forestry, Stockholm

WITH THE WORLD'S GROWING population, interest is increasingly focused on the resources that in the near or more distant future will be available for this population. One of the most important resources refers to the worlds forests with their stand of timber meeting the most varying requirements in construction and housebuilding, for fuel, as paper and board, as a raw material for textiles and a wide range of chemical products, and so forth.

The comprehensive study presented in *World Timber, Trends and Prospects* is the first attempt at a forecast of future supply and demand of timber for various purposes on a worldwide scale. It is founded on a thorough analysis of the trends as well of production and consumption as of trade in forest product and, moreover, on the author's thorough acquaintance with the principal forest regions and markets of forest products.

The following list of the principal chapters of the study will give an idea of its method and contents.

Cut and Consumption of Wood, Trends in World Consumption of Forest Products and Wood, Prognoses for the Future Consumption of Forest Products, World Forest Resources, Forest Resources and Wood Requirements in Various Regions, World Production and Trade in Forest Products, Summary, Conclusions, Future Demand for Wood, Future Supply of Wood, and Future Development in Different Regions.

The author, Dean of the Royal School of Forestry at Stockholm, has an international reputation in forestry. He is a graduate of the school which he now heads, also of the College of Commerce at Stockholm, and he received a Master of Science degree from the University of Stockholm. The University of Uppsala in Sweden and the Universities of Göttingen in Germany and Helsingfors in Finland have awarded him honorary doctoral degrees.

Thorsten Streyffert has been professor of forest economics at the Royal School of Forestry since 1939 and its rector since 1947. He has served the Food and Agricultural Organization of the United Nations as forest economist. In the course of his work in forest economics, he has traveled in the United States (he was a visiting professor at the School of Forestry, Oregon State College), the Soviet Union, India, Japan, and China. Prof. Streyffert is the author of several books and many articles in his specialized field.

World Timber consists of 246 pages, 73 tables, and 29 maps and diagrams. Bound cost—Swedish Kronor 40.

Scanning World Wide Forest Products Publications

Production and Properties of Insulation Type Particle Board. W. Klauditz, H. J. Ulbricht and W. Kratz. *Holz a.R. uW,* V. 16, No. 12. (English summary).

Insulation-type particle boards from thin and flat engineered particles of spruce, pine, poplar and beech as well as from flax straw were experimentally produced with a resin-content (urea-formaldehyde-resin) of about 6.9% within a density range of 0.30 to 0.50 g/cm³. Some technological data of the testboards, as bending strength, tensile strength perpendicular to surface, compression strength and linear expansion in thickness were determined. Furthermore the investigations included examinations of boards made from spruce sawdust. From the results obtained it became evident that insulation type particle boards with a density of 0.3 to 0.4 g/cm³ possibly can attain technical and practical importance.

Studies on Water-Borne Wood Preservatives. Takeo Shibamoto, Yoshiyuki Inoue, and Yoshihisa Kenjo. *J. of the Japan Wood Research Society,* V. 5, No. 1:31. Feb., 1959. (Summary and tables in English)

The standard wood block method recognized as Japanese industrial standard A 9302 was slightly modified for comparing the effectiveness and permanence of 48 kinds of preservatives. The results obtained are as follows:

(1) In the case of Malenit and some allied mixtures, the effect of addition of sodium 4, 6-dinitro-o-cresylate in place of dinitrophenols and chromium trifluoride was somewhat remarkable.

(2) Potassium bichromate and disodium hydrogen arsenate are less toxic than fluoride. In this condition, they are considered to be negative toxic.

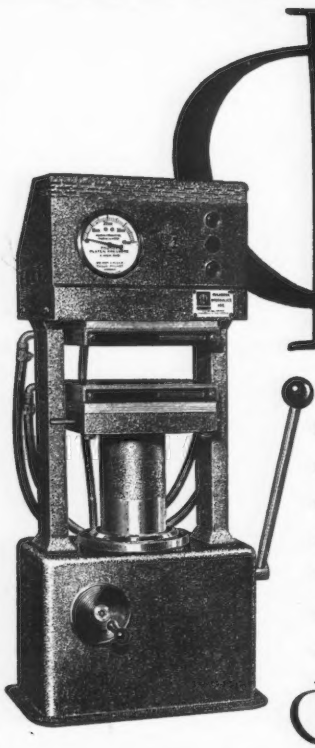
(3) Of the preservatives containing arsenic compounds, the effective value of sample No. 22 containing no sodium 4, 6-dinitro-o-cresylate was quite poor. It seems that the leachability of sodium fluoride was not much reduced by the addition of potassium bichromate, but not in the case of disodium hydrogen arsenate; presumably it combined with bichromate to yield chromium arsenate. Even if chromium cryolite and chromium arsenate were formed, they will not be so poisonous at low concentration. At first, the next reaction will occur by the reduced action of wood.

$$K_2Cr_2O_7 + 2Na_2HAsO_4 + 2H_2O \rightarrow 2CrAsO_4 + 4NaOH + 2KOH + 3O$$

(4) In the fire-retardant preservatives, the toxic effect of addition of diammonium hydrogen phosphate or ammonium sulphate was quite negative.

(5) The effective values of 0.6% Boliden salt S 25 and allied salt mixtures were negative. p-Nitrophenol, added in Boliden salt, promoted the preserving effectiveness at low concentration of their salt and inhibited the growth of molds.

(6) Sodium p-nitrophenate or sodium pentachlorophenate, copper sulphate and potassium bichromate dissolved in ammonia water have great effectiveness after 15 to 25 times of weathering procedure.



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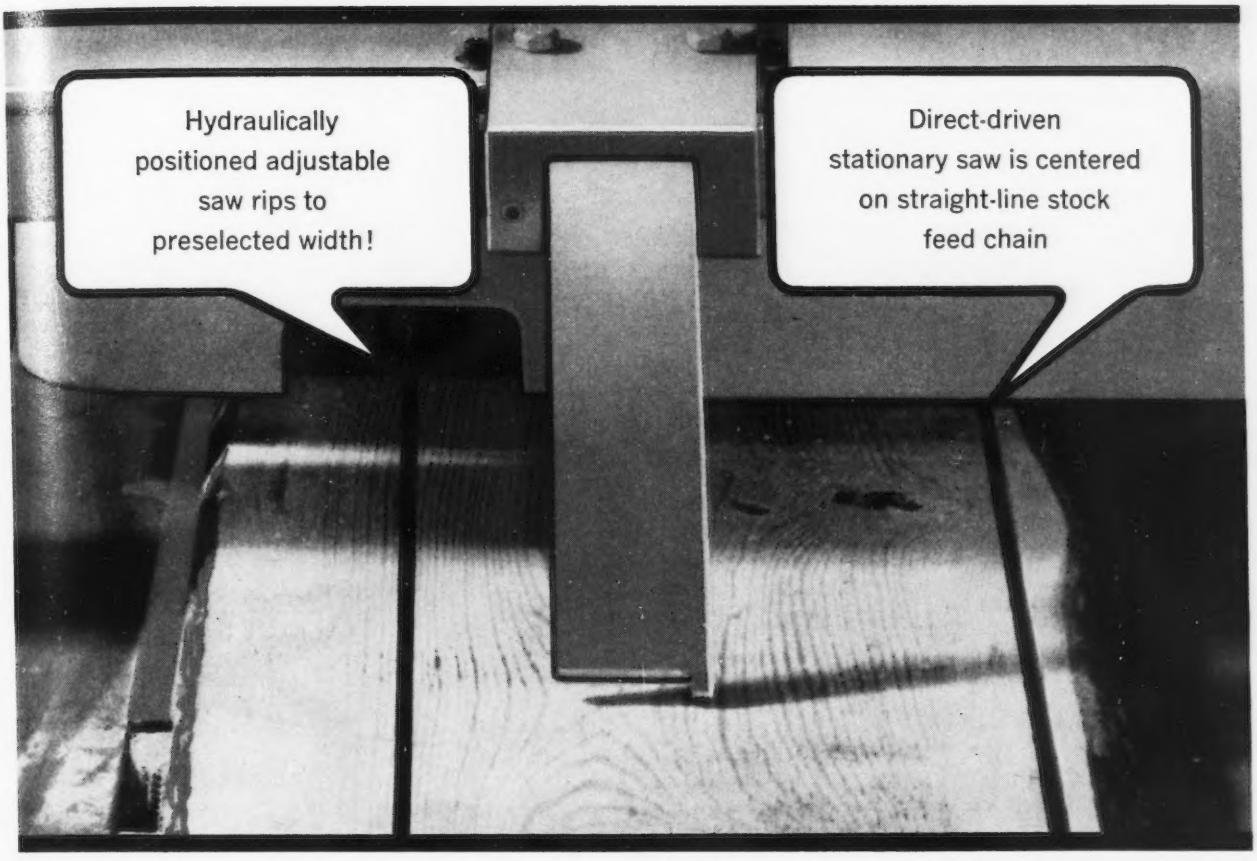
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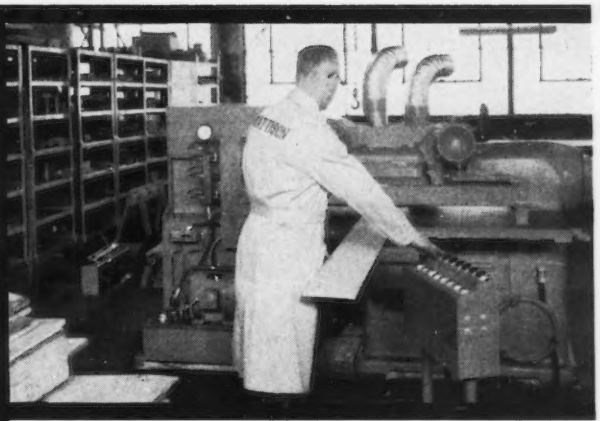

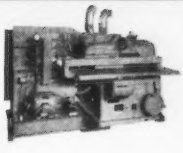

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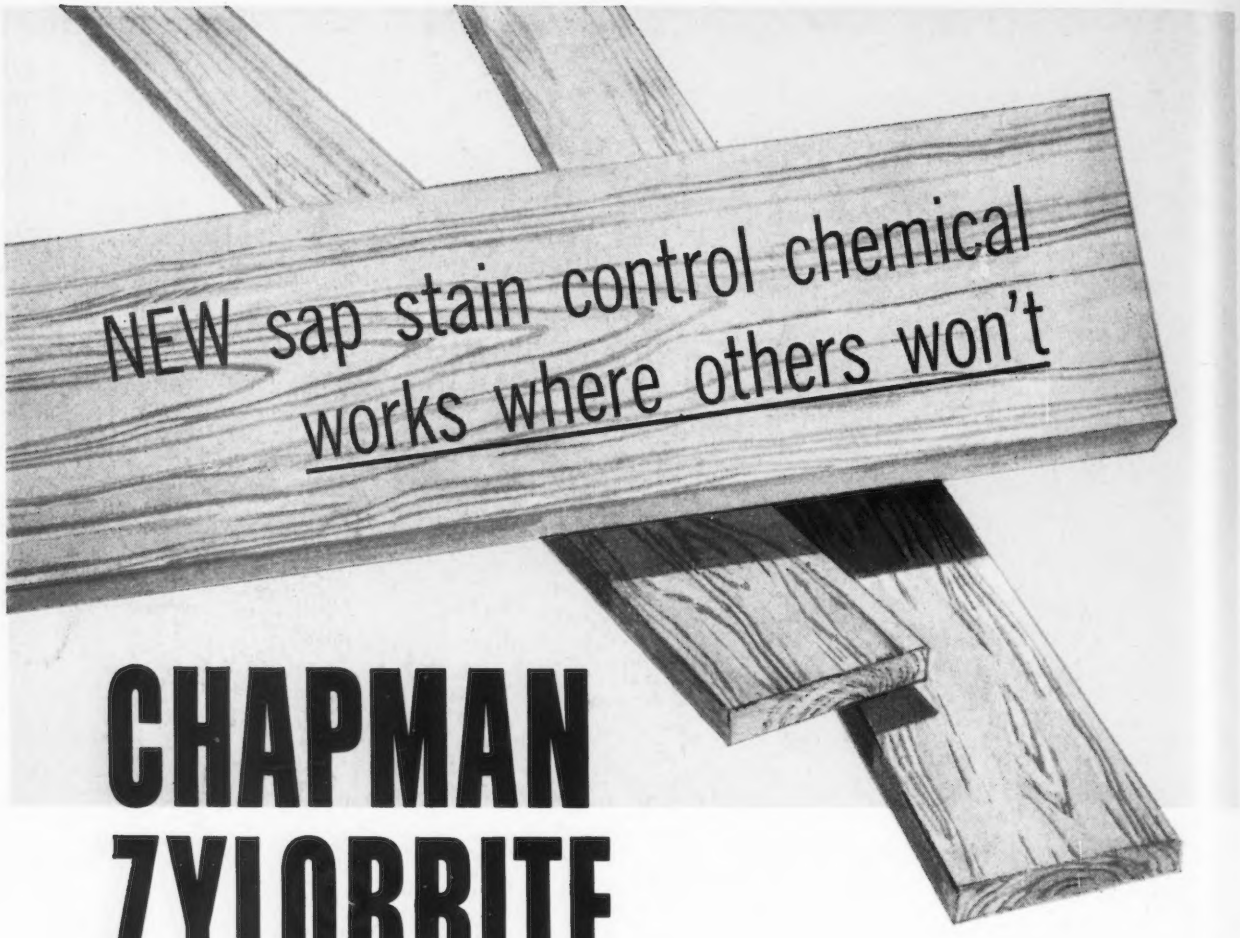

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